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Optimal Levels of Fertilization Under Risk: The Potential for Corn and Wheat Fertilization Under Alternative Price Policies in Argentina*

ALAIN DE JANVRY

Because economic return from fertilization is stochastic, a precise assessment of the risk in fertilizer investment is critical, especially in less-developed countries. Using corn and wheat fertilizer response data from the Argentine Pampa, production conditions under which use of fertilizer would be economical are determined. Government protection of an obsolete fertilizer industry, high fertilizer prices, and inadequate tax breaks for users retard development of modern fertilizer technology. Despite current prices, fertilization would be possible on a majority of Argentine farms. Lack of use is attributed to the unavailability to farmers of technical and economic information. Social gains from alternative fertilizer price policies are calculated.

PARTICULARLY in nonirrigated farming, the physical outcome of fertilization is stochastic since it depends upon noncontrollable climatic events. The economic return from fertilization is, hence, itself stochastic; and it is of importance to assess as precisely as possible the level of risk that farmers assume when they invest in fertilizers. This is especially true in many less-developed countries where farmers face relatively unfavorable input-output price ratios, thus working within narrow profit margins. These farmers in addition usually do not have the financial resources to bear losses in bad years, since fertilizers are purchased on short-term credits without insurance schemes that would allow them to spread over successive crops the risks assumed in any one year. Finally, farmers may be only in the early process of adopting fertilizers as a new technology, and a failure to assess the risk they have to assume in using particular fertilizer doses may lead to serious setbacks in the spread of technological changes. This is especially relevant now when promoting further geographical expansions of the Green Revolution is of such concern.

Added to these considerations is the fact that fertilizer trials are scarce, again particularly in less-developed countries; and it is useful to try to extrapolate the experimental results av able to other climatic and production co: tions. This can be done partially by cha terizing the distribution function of the controllable factors that affect yields.

In this paper a method to assess the risk tached to the application of particular tilizer doses is proposed. The frequency tribution of the internal rates of return t can be gotten from any specific investmen fertilizers is obtained. Of particular inte here is the probability that farmers n recover at least the cost of using fertilizers

The method is applied to Argentine dat: corn and wheat fertilizer response in the hu Pampa under nonirrigated conditions. I used to assess the production conditions ur which present use of fertilizers is economi This leads to a partial interpretation of causes of technological stagnation in country. It also permits an estimation of economic returns from fertilization if rela prices were lower than at present. In doing a rough lower estimate of the social ret from alternative fertilizer price policies ca obtained.

Strategy

Fertilizer response of corn and wheat is termined by a set of controllable and : controllable factors. Other than fertilizer d and cultural practices, the most important trollable factor is soil fertility which is termined in part by recent use of the l Cereal-intensive crop rotations will gene deplete the natural fertility of the land, fertilizers play the role of substitutes for lost fertility. The lower the soil fertility,

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ALAIN DE JANVRY *is assistant professor of agricultural economics at the University of California, Berkeley, and Ford Foundation project specialist in Argentina.*

higher fertilizer response is expected to be.[1] These considerations indicate that, in studying fertilizer response in the context of production functions, it is indispensable not only to characterize soil fertility as a determinant of yield but also to allow for interactions between fertilizer and soil fertility. In this way the estimated marginal productivity of fertilizer may shift downward when soil fertility increases, even though soil fertility and yield have a positive direct relationship. Soil fertility is characterized in this paper by its content of organic matter.[2]

Noncontrollable factors may or may not be stochastic. Among the nonstochastic ones are the natural characteristics of the soil, for example, its permanent wilting point. Stochastic factors are weather characteristics such as hail, frost, rainfall, and temperature. In analyzing experimental data of the type here, the consequences of the two first events appear as binomial variables since some trials are characterized as having failed because of hail or frost; and their results are not reported, presumably because yields would not have been sufficient to cover harvesting costs. Rainfall and temperature affect yields differently depending on the growth stage of the crop. Rainfall will be characterized by soil humidity or by quantity of rain in each of several critical periods of the growth of corn and wheat—seeding and tasseling for corn and seeding, stooling, and tasseling for wheat. Because substitution and/or complementarity possibilities exist between periods of rain in different critical periods, it is necessary to determine the joint probability of rainfall events in the various critical periods that permit the attainment of the same level of yield.

Specify a response function of the class

$$Y = A \prod_{i=1}^{K} X_i^{f_i(X)} e^{g(X)}$$

where $f_i(\boldsymbol{X})$ and $g(\boldsymbol{X})$ are polynomials of any degree in the arguments of the vector X of factors of production. If $g(\boldsymbol{X})=0$ and $f_i(\boldsymbol{X}) = \alpha_i$, the function reduces to a Cob if $g(\boldsymbol{X})=\sum \beta_i X_i$ and $f_i(\boldsymbol{X})=\alpha_i$, it a transcendental function [6]; and it reduces to a Cobb-Douglas wi elasticities of production [11].

On the basis of the above con specialize it to

$$Y = A N^{f_N(M)} F^{f_F(M)} \cdot e^{g(N,F,NF)} M^{b_5} R \prod_i X_i^{\gamma_i}$$

where

Y = yield
N = nitrogen
F = phosphorus
M = organic matter the land
R = stochastic inde izing weather
X_i = cultural practic and the soil con
D_j = geographical o dummies
$f_N(M)$ and $f_F(M)$ = polynomials in using a goodne terion, were fc generally best quadratics

$$f_N(M) = b_1 + b_2 M^2, \qquad f_F(M) =$$

and

$g(N, F, NF)$ = a linear functic and NF; since tl parameters of t turned out neve nificant, it is the following de

The weather index R is of the form

where W_k denotes soil moisture or r ditions in the kth critical period.

If

$$\alpha_0 = A M^{b_5} \prod_i X_i^{\gamma_i} e^{\sum_j \delta_j D}$$

$$\alpha_1 = b_1 + b_2 M^2$$

$$\alpha_2 = b_3 + b_4 M^2$$

the function reduces to a Cobb-D variable parameters in the only two have prices and about which an ec cision has to be made

$$Y = \alpha_0 R N^{\alpha_1} F^{\alpha_2}.$$

[1] At least within a reasonable range of depletion where the structural characteristics of the soil have not been destroyed.

[2] Because the soil never freezes in the Argentine corn belt, decomposition of organic matter occurs all through the fall and winter months. Consequently, a high percentage of the organic matter in the land is in assimilable form at seeding. r this reason, organic matter offers a good characterization of soil fertility.

For a maximum in the profit function to exist, it is necessary to have

$$b_1 + b_3 + (b_2 + b_4)M^2 < 1.$$

Equating the marginal productivities to price ratios for N and F, the optimum fertilizer doses N_0 and F_0 are given by

$$\log N_0 = \frac{1}{1-\alpha_1-\alpha_2}\left[\log \alpha_0 R - (\alpha_2 - 1)\log \alpha_1 + \alpha_2 \log \alpha_2 + (\alpha_2 - 1)\log(1+r)\frac{P_N}{P} - \alpha_2 \log(1+r)\frac{P_F}{P}\right],$$

$$\log F_0 = \frac{1}{1-\alpha_1-\alpha_2}\left[\log \alpha_0 R - (\alpha_1 - 1)\log \alpha_2 + \alpha_1 \log \alpha_1 + (\alpha_1 - 1)\log(1+r)\frac{P_F}{P} - \alpha_1 \log(1+r)\frac{P_N}{P}\right].$$

Here, P is the product price while P_N and P_F are the prices of nitrogen and phosphorus, respectively; r is the interest rate over the period between seeding and the sale of the product.

If the levels of N and F are set equal to one when no fertilizer is applied and the yield obtained from the economically optimum fertilizer doses is denoted by Y_0, the percentage internal rate of return on the fertilizer investment is

$$IRR_0 = \left[\frac{P(Y_0 - \alpha_0 R)}{(1+r)(P_N N_0 + P_F F_0)} - 1\right]100.$$

This internal rate of return is a stochastic variable since the weather index R is stochastic. Costs will be covered if $IRR_0 \geq 0$, and it is important to characterize the probability that this occurs. In general, it is necessary to characterize the frequency distribution of IRR_0 conditionally upon the levels of N and F and for given prices, M, X, and D so that farmers may decide upon the levels of fertilizer use according to their aversion for risk.

In the studies of Barger and Thom [1], the cumulative frequency distribution of rainfall, within intervals of one or several weeks, is well adjusted by the incomplete gamma function. Using monthly rainfall reports, the incomplete gamma function can be adjusted

$$F(x \geq X) = 1 - \frac{1}{\beta^\gamma \Gamma(\gamma)}\int_0^X x^{\gamma-1} e^{-x/\beta} dx$$

where x is millimeters of rainfall in one month. Thom's approximation of the maximum likelihood estimator $\hat{\gamma}$ of γ, which is given by the solution of the quadratic equation, is used,

$$12Z\gamma^2 - 6\gamma - 1 = 0$$

where Z is the natural logarithm of the ratio of the arithmetic to the geometric mean of x, that is,

$$Z = \log \bar{x} - \frac{1}{N}\Sigma \log x$$

n being the number of observations. The maximum likelihood estimator of β is then [13, p. 391]

$$\hat{\beta} = \overline{X}/\hat{\gamma}.$$

Karl Pearson's table of the incomplete gamma function can be used to tabulate the function [9]

$$\Gamma(u, p) = \frac{1}{\Gamma(p+1)}\int_0^{u(p+1)^{1/2}} y^p e^{-y} dy$$

where $p = \gamma - 1$, $y = x/\beta$, and $u = x/(\beta\gamma^{1/2})$.

There exists a one-to-one correspondence between IRR and the weather index R for given P_N/P, P_F/P, r, M, X, and D plus either the profit maximation rule or given levels of N and F. And since

$$\log R = \Sigma \beta_k \log W_k,$$

there is an infinity of combinations of rainfall patterns, characterized by the levels of $W_1, W_2, \cdots, W_K$, that permit the attainment of the same internal rate of return.[3] For given levels of $W_1, \cdots, W_{K-1}$, the level of W_K that will satisfy a given iso-R curve of level R_0 (say) is

[3] This method tends to overestimate the probability of reaching a particular yield level if the elasticity of substitution between rainfalls in different periods is in fact less than one. W_k should then be introduced in the weather index with a functional form different from the Cobb-Douglas. In particular, if there is more complementarity than substitutability among rainfalls in successive periods, interactions among them with positive expected signs should be specified.

$$\log W_K = \frac{1}{\beta_K}\left[\log R_0 - \sum_{k=1}^{K-1} \beta_k W_k\right]$$
$$\text{or } W_K = h(W_1, \cdots, W_{K-1}/R_0).$$

Assuming the W's to be independently distributed gamma variables, the cumulative density function of R will be obtained by integrating over the variable interval of integration

$$F(R \geq R_0) = q \int_{W_1=0}^{\infty} \int_{W_2=0}^{\infty} \cdots \int_{W_K=h(W_1,\cdots,W_{K-1}/R_0)}^{\infty} f(W_1)f(W_2)\cdots f(W_K)dW_1dW_2\cdots dW_K.$$

q is the binomial probability that the crop will not be destroyed by cataclysmic events like hail or frost. Since the parameters of the gamma functions are nonintegers, an analytical solution to this integration does not exist. Numerical integration is needed.

Once the frequency distribution of R and, hence, of yields and of internal rates of return has been obtained, it is used to find the optimal fertilizer doses for a given level of risk aversion and for given prices, r, M, D, and X variable levels. Optimality is defined as the maximization of expected profits.[4] Risk aversion corresponds to a statement about a probability level that characterizes the chances with which an individual wants to cover at least the cost of fertilizer use in any particular year. For example, a producer may want to be 100 α-percent sure not to lose money in his fertilizer investment. The objective function is then to maximize expected profits once the priority goal $Pr(IRR_0 \geq 0) = \alpha$ is satisfied.

Unconstrained maximization of expected profits is not an acceptable criterion here because the variance of profits may be large and, hence, the probability that losses be incurred high. By restricting the solution to satisfy $Pr(IRR_0 \geq 0) = .95$, for example, fertilizer use is forbidden when costs may not be covered in more than one year out of 20. The constraint determines the subset of the space (P_N/P, P_F/P, r, M, X, D) over which maximization of expected profits can be performed as risk aversion requirements are met. Hence, this is a case of lexicographic preferences where the priority goal is to cover cost with probability α and the secondary objective is the maximization of expected profits.

Of particular interest is the combination of prices, r, M, D, and X levels that lead to a zero internal rate of return for a given level of risk aversion. Specifically, there is interest in the relation

$$\frac{P_N}{P} = f\left[M/Pr(IRR_0 \geq 0) = \alpha, \frac{P_F}{P}, r, X, D\right]$$

which can be named the "fertilization possibility frontier." It describes the set of relative nitrogen prices and soil fertility combinations for which fertilizer costs are just covered at the specified level of risk aversion. Profits are positive below this curve and negative above it. It shifts upward with lower levels of risk aversion and with increases in the X's and D's that are positively related to yield. In doing so, the area with a potential for fertilizer use expands.

To determine the fertilization possibility frontier, the value R^* of the weather index is found to be such that $Pr(R \geq R^*) = \alpha$. R^* is used to solve for N_0, F_0, Y_0, and IRR_0. The locus of points where $IRR_0 = 0$ is the frontier since $Pr(IRR \geq IRR_0) = \alpha$.

Analysis

Well-controlled experiments on fertilization were conducted in Argentina for the first time on wheat in 1969–70 and since 1967–68 on corn. Few data are available, and it is important to assess the results obtained in a probabilistic framework in order to evaluate their generality and to extrapolate them to other climatic conditions.

Fertilizer use on cereal crops is almost nonexistent in Argentina. It has been estimated that some 0.2 percent of the acreage seeded in corn was fertilized in 1968. Wheat fertilization is slightly more frequent, mainly because certain areas have been continuously dedicated to that crop and now face serious drops in soil fertility and erosion problems. Nevertheless, in the area where fertilizers are most widely spread, a recent survey [12] indicated that only about 12 percent of the area planted in wheat had been fertilized. As a result, Argentine yields of corn and wheat which, 50 years ago, were similar to the ones obtained in the

[4] Defined here as net income and not in the Knightian sense of the difference between *ex ante* and *ex post* returns.

United States are now only about half as high.[5]

While grain prices are substantially below world market levels at the farm gate in Argentina (in part because of the secular undervaluation of the exchange rate which adds an export tax that generally oscillates between 5 and 10 percent according to the parity of the peso to the dollar), nitrogen prices are about three times higher at the farm level in Argentina than in the United States. Imports of anhydrous ammonia in large quantities are generally not possible because of lack of storage facilities and a tax rate of 70 percent. Imports of urea (which is the main form under which nitrogen is presently applied), ammonium sulfate, and compounds were totally forbidden as of December, 1970.[6] Phosphates, on the contrary, are not produced in Argentina and are imported tax free. Their prices at the farm level are comparable to those found in the United States.

Table 1 shows the absolute and relative prices of nitrogen, phosphorus, corn, and wheat in Argentina and the United States in 1969. All prices are at the farm level. It shows that, while the relative price of nitrogen to corn is 2.0 in the United States (that is, the United States farmer needs to sell 2 tons of corn to buy 1 ton of nitrogen), it is 8.1 in Argentina—four times higher. It is particularly interesting to note that, if Argentine farmers could buy their nitrogen at U. S. prices while still selling their corn at Argentine prices, the relative price would drop to 2.9. For wheat, the relative price would drop from 7.5 to 2.7. By contrast, phosphorus prices are similar in Argentina and the United States, the price ratio of phosphorus to wheat being somewhat higher in Argentina (4.4 compared to 3.9) since wheat prices are lower.

The data used to fit a response function for corn were obtained by the Instituto Nacional de Tecnologia Agropecuaria (INTA), the national institute of agronomic research, on experimental plots located on farms in the area of Marcos Juarez and supposedly managed according to current practices.[7] The estimated function is

$$\log Y = -15.031 + .117 \log N - .010\, M^2 \log N \\ \quad (-5.19) \quad (3.00) \qquad (-1.95)$$

$$+ 2.116 \log M - 1.379 \log PW \\ (4.27) \qquad (-3.82)$$

$$+ 3.463 \log HS + 1.940 \log HF \\ (6.10) \qquad (3.62)$$

$$+ .392 \log PD,\ R^2 = .77 \\ (11.32)$$

where

Y = corn yield in tons per hectare
N = kilos of nitrogen per hectare
M = percent of organic matter of soil
PW = permanent wilting point in percent of water
HS = percent of soil humidity at seeding
HF = percent of soil humidity at tasseling
PD = plant density at harvest in thousands per hectare

Table 1. Prices of corn (C), wheat (W), nitrogen (N), and phosphorus (F) in the United States and Argentina, 1969

	United States	Argentina
	U. S. dollars per bushel	
Corn	1.16	.806
Wheat	1.15	.914
	U. S. dollars per ton	
N from ammonium	92	289
N from urea	182	255
F from superphosphate (46 percent)	161	196
Phosphorus from 18-46-0[a]	165	147
P_N/P_C with N from ammonium	2.0	9.2
P_N/P_C with N from urea	3.8	8.1
$P_{N,US}/P_{C,Arg.}$ with N from ammonium	2.9	
$P_{N,US}/P_{C,Arg.}$ with N from urea	5.7	
P_N/P_W with N from ammonium	2.2	8.6
P_N/P_W with N from urea	4.3	7.5
$P_{N,US}/P_{W,Arg.}$ with N from ammonium	2.7	
$P_{N,US}/P_{W,Arg.}$ with N from urea	5.4	
P_F/P_W	3.9	4.4

[a] P_N = \$92 per ton (U. S.) for the United States and \$255 per ton (U. S.) for Argentina.

[5] Genetic improvements were aimed at maintaining yields on soils of secularly declining fertility. By contrast, the spectacular increase in U. S. yields results from the interaction of genetical and chemical innovations.

[6] Since January 1, 1971, import of all nitrogenous fertilizers has been forbidden, officially to protect the national industry from dumping which is taking place on the world market.

[7] A detailed account of the experimental data is given in de Janvry [3]. In de Janvry and Koenig [4], several other experiments conducted by INTA are analyzed with the same methodology and provide results highly consistent with the ones reported here.

Table 2. Corn fertilization possibility frontier with 95 percent risk aversion[a]

IRR$_0$ = 200 IRR$_0$ = 0

IRR$_0$ = 300

$\frac{P_N}{P}$ \ M	2.0	2.2	2.4	2.6	2.8	3.0	3.2	3.4	3.6
9	35 210	37 219	37 225	35 226	31 221	24 203	14 159	-	-
8	39 220	42 229	42 235	40 236	35 231	27 214	16 170	-	-
7	45 230	48 240	48 246	46 248	40 243	31 227	18 183	-	-
6	54 243	57 253	57 259	54 262	47 257	36 241	21 198	-	-
5	65 257	69 267	69 274	65 277	56 274	43 258	25 216	-	-
4	83 275	88 285	88 293	82 296	71 293	54 279	32 238	3 20	-
3	114 297	119 308	119 316	111 320	96 319	73 305	43 265	4 48	-
2	176 327	184 339	183 348	170 353	146 354	111 342	64 304	7 89	-

[a] The data that appear in each cell are the optimum nitrogen doses N_0 in kg/ha; the internal rate of return corresponding to N_0: IRR_0 in percent.

and

data in parentheses are t ratios.

The distribution function of soil humidity was derived from the one of rainfall by using a linear relationship between the two and estimated from seven years of numerous measurements of soil moisture in corn fields. Table 2 gives the fertilization possibility frontier for a level of risk aversion of 95 percent. An interest rate of 5 percent, a plant density of 60,000, and the average observed permanent wilting point level of 13.8 percent were used. The fertilization possibility frontier appears to be relatively insensitive to price and corresponds to a soil fertility of 3.4 percent of organic matter. According to soil scientists, about half of the acreage presently planted in corn would fall within the frontier [8]. Since this land corresponds mainly to smaller farms that have crop-intensive rotation patterns, it means that, at this level of risk aversion, about 75 percent of the corn-producing farms could actually make use of fertilizers.

Expected profits are maximized within the fertilization possibility frontier. Table 2 gives the optimum levels of fertilizer use, N_0, and the corresponding internal rates of return, IRR_0, for various combinations of relative prices and soil fertility. It shows that even under present prices of 8 to 1 fertilizers could be used with profits on lands with up to 3.2 percent organic matter at the 95 percent risk aversion level. If fertilizer prices would drop to the world market level of 3 to 1, doses three times higher could be used and rates of return 50 percent higher obtained on lands with up to 3.4 percent organic matter.[8]

Data on wheat fertilizer response were generated in 1969–70 by the INTA-Cimmyt-

[8] Because of extensive dumping of nitrogen on the world market, the conservative assumption is made that Argentina could import this fertilizer with a consequent farm level price equal to the United States price.

Table 3. Fertilizer response functions for wheat, 1969/70

Region	Intercept	Variables[a]								R^2
		Log N	Log F	Log M	M^2 Log N	M^2 Log F	Log LS	Log LM	Log LF	
II-North (Marcos Juarez)	− .1862 (− .267)[b]	.0333 (1.267)	− .0113 (− .429)	.9431 (3.012)	− .0051 (−1.097)	.0018 (.379)	.0594 (.348)	− .0847 (−6.095)	− .0299 (−1.943)	.81
II-South (Pergamino)	.4949 (.772)	.1515 (3.251)	.1059 (2.216)	.5531 (1.100)	− .0221 (−2.959)	− .0147 (−1.910)	.4987 (8.184)	.3825 (7.361)	− .7283 (−4.990)	.73
III (Entre Rios)	2.6327 (9.662)	.0278 (1.100)	.0145 (.575)	−1.6804 (−8.542)	− .0012 (− .826)	.0021 (1.479)		.0005 (.013)		.94
IV (Balcarce)	.1924 (1.438)	.0246 (2.255)	.0986 (8.470)	.3246 (7.963)	− .0002 (− .632)	− .0015 (4.836)	− .1000 (−4.174)	− .0667 (−1.265)	.1510 (2.556)	.86
V-South (Bordenave)	− .3593 (−1.296)	.0394 (1.103)	− .0571 (−1.410)	.7932 (2.597)	− .0048 (− .873)	.0150 (2.420)				.87

[a] N = nitrogen in kg/ha; F = phosphorus in kg/ha; M = percent organic matter; LS = mm rainfall at seeding; LM = mm rainfall at stooling; LF = mm rainfall at tasseling.
[b] Data in parentheses are t ratios.

Ford Foundation program [7] for all the ecological regions of Argentina. The response functions estimated are given in Table 3 for regions II-North (Marcos Juarez), II-South (Pergamino), III (Entre Rios), IV (Balcarce), and V-South (Bordenave). Data for regions I (Santa Fe) and V-North (Cordoba) were not available.

In several cases, rainfall had adverse effects on yields because of the consequent development of weeds and pests. In general, the lack of control of weeds and pests in the experiments led to a severe underestimation of fertilizer response since intensity of the attack and fertilizer response increased with rainfall.[9] Again, incomplete gamma functions were adjusted to the distributions of LS, LF, and LM and integrated numerically to obtain the cumulative frequency distribution of the weather index R.

Table 4 gives the fertilization possibility frontier for a level of risk aversion of 95 percent in region II-South. Under present prices and according to the data analyzed, which obviously need to be complemented, fertilizer use would not be possible in region II-North[10] but possible on lands with up to 2.7 percent organic matter in region II-South and on the whole acreage in regions III and IV. The same table also gives the optimum nitrogen (N_0) and phosphorus (F_0) doses and the corresponding internal rate of return (IRR_0) for various combinations of nitrogen prices and soil fertility for region II-South. They are calculated similarly for the other regions. A relative price of 4 was used for phosphorus.

In region II-South the fertilization frontier corresponds to a soil fertility of 2.7 percent which is lower than for corn at the same level of risk aversion. But wheat is typically grown on more exhausted lands than corn, either because it follows corn, sorghum, or sunflower in the crop rotation patterns [5, p. 107] or because some areas have been permanently sown in that cereal. It is estimated that half of the present wheat acreage in that region would fall within the fertilization possibility frontier.

A notable aspect of the results obtained is that, while optimum fertilizer doses and their corresponding internal rates of return are highly sensitive to climatic conditions, the steepness of the IRR_0 function where it intersects the $(P_N/P, M)$ space implies a high stability of the location of the fertilization possibility frontier. For this reason, the frontier will expand only slightly with lower levels of risk aversion. For example, with a risk aversion level of 75 percent, the corn frontier would shift from 3.3 to 3.4 percent organic matter at current prices.

Implications

Under the present fertilizer price policy, a double tax write-off is allowed farmers on their fertilizer costs. But the small farmers whose lands lie within the fertilization possibility frontier because they are used intensively and

[9] Control was exercised several times *ex post*, that is, after an outbreak of weeds or pests made it necessary, and not *ex ante* as either a systematic practice or part of the experimental design.

[10] The analysis of earlier results [4] shows significant fertilizer response in that region, too.

Table 4. Optimum level of wheat fertilization in region II—South (Pergamino)[a]

P_N/P \ N	1.0	1.2	1.4	1.6	1.8	2.0	2.2	2.4	2.6	2.8
9	70 109 183	66 105 189	58 93 195	49 79 198	38 63 199	28 47 193	18 31 177	9 18 137	1 5 15	-
8	80 113 186	75 106 193	66 95 198	55 80 202	43 63 203	31 47 198	20 32 183	10 18 143	1 5 18	-
7	94 115 190	88 109 197	77 96 203	64 81 207	50 64 208	36 47 204	23 32 189	12 18 149	1 5 21	-
6	112 118 194	105 111 201	92 98 207	76 82 212	59 65 214	43 48 211	27 32 196	14 18 157	1 5 25	-
5	138 122 199	129 114 206	113 101 213	94 84 218	73 66 221	52 49 218	33 32 205	16 18 166	1 5 29	-
4	180 127 204	167 118 212	146 104 220	120 86 226	93 68 229	66 49 228	42 33 215	20 18 177	2 5 35	-
3	251 133 211	232 123 220	202 108 228	165 89 235	127 69 240	90 50 239	57 33 228	28 18 191	2 5 42	-
2	403 142 221	371 131 230	320 113 239	259 93 248	198 72 254	139 52 256	87 34 246	42 18 210	3 5 52	-

$IRR_0 = 200$ $IRR_0 = 0$

[a] The data that appear in each cell are the optimum nitrogen (N_0) and phosphorus (F_0) in kg/ha; the corresponding internal rate of return (IRR_0) in percent.

who could make a good use of fertilizers to relax their land constraint typically have incomes below taxable levels. Large farmers who do pay income taxes have lands above the fertilization frontier and, hence, do not need fertilizers. Ironically, the tax write-off approach as an incentive to fertilizer use is irrelevant for both categories of farmers.

High fertilizer prices are maintained through import tariffs and restrictions that protect a monopolistic national fertilizer industry which is technologically obsolete and operates below full capacity because of inadequate demand at prevailing prices. Establishment and protection of this industry are typical of the import substitution policies in which Argentina and most other Latin American countries engaged after World War II. Also typical are the prevalence of industrial over agricultural interests in economic policy and the disregard of the external cost of industrial protectionism on agricultural productivity growth. An alternative policy would consist of capitalizing on the extensive dumping of nitrogen on the world market to permit temporary imports that would lower nitrogen prices at the farm gate to levels comparable to the ones observed in the United States.[11] Once fertilizer demand was sufficiently high, a modern technology fertilizer industry could be developed in Argentina.

Present Argentine nitrogen consumption is 30,705 tons a year. Modern centrifuge compression plants producing 1,000 tons a day have

[11] A study of Tennessee Valley Authority [10] calculates that the world demand for fertilizers in 1970 is satisfied with 79 percent of world-invested capacity and that large production surpluses will exist at least until 1975 in the United States, Europe, and Japan.

costs 40 percent below the present 200 tons a day plant. From the previous analysis, the present potential demand for nitrogen, both at actual and world price levels, can be estimated. This permits an assessment of the possibility of operating a low-cost fertilizer industry in Argentina.

Assuming that soil fertility is uniformly distributed between M_1 and M_u,[11] where M_u is on the fertilization possibility frontier, the optimum consumption of nitrogen in each crop and region is given by

$$S\int_{M_1}^{M_u}\left[N_0 \Big/ \frac{P_N}{P}, \frac{P_F}{P} = 4, M, X, D; \right.$$
$$\left. Pr(IRR \geq 0) = .95\right] f(M)dM$$

where S is the total area actually harvested in that crop that lies within the interval of integration. Taking $M_1 = 1.5$ percent for wheat and 2.0 for corn, the optimum total yearly nitrogen consumption is calculated to be 97,694 tons when relative prices are 8 and 281,853 tons when they drop to 3. Added to present consumption, the totals are 128,399 tons under present prices and 312,558 tons under potential prices. Thus, it would seem possible to establish a modern industry in Argentina as soon as fertilizer use is adopted by farmers within the production possibility frontier.

A lower bound to the social rates of return can be estimated by following this alternative fertilizer price policy. The net return per hectare of lowering fertilizer relative prices from 8 to 3 is given for each crop and region by

$$S\int_{M_1}^{M_u} P[(\Delta Y_0 - 3N_0 - 4F_0)$$
$$- (\Delta Y_0' - 8N_0' - 4F_0')]f(M)dM$$

where ΔY_0 is the increment in yield due to application of the optimum fertilizer doses N_o and F_0 for given prices, M, X, and D. Assuming again that acreage harvested remains the same as in 1969, the total net return from lowering fertilizer prices would be \$23 million (U. S.) per year. If it is estimated that the cost of shifting to this new fertilizer price policy would be (1) to compensate the owners of the existing fertilizer industry at the full present value of their investment which is \$15 million (U. S.) in order to close it down and (2) to invest \$10 million (U. S.) in storage facilities in the Buenos Aires harbor to facilitate bulk imports,[13] then the internal rate of return on this investment would be 92 percent in a single year. With an 8 percent discount rate and a 10-year horizon over which it is assumed, conservatively, the price ratio of 3 to 1 will be maintained (Argentina can be considered a price taker on the world market for cereals—it presently exports 56 percent of its corn and 43 percent of its wheat crops), the internal rate of return would be 622 percent. This estimate is definitely an understatement of the benefits Argentina could derive from this new policy since (1) it is anticipated that the acreages planted in corn and wheat would expand as fertilizer prices drop, since the need to rotate land with pastures to maintain soil fertility would decrease and the relative profitability of these crops increase; (2) fertilizers would also be used on other crops and on pastures; and (3) external benefits of this investment on labor employment by agriculture and, in general, its impact on the rest of the economy through generation of higher agricultural surpluses and the relaxation of the foreign exchange constraint to industrialization are not taken into consideration.[14]

A question of importance is why fertilizers are nearly unused on wheat and corn today when, even at present prices, they could safely yield acceptably high rates of return on nearly half of the wheat and corn acreages. A host of rationalizations has been offered—speculation on land values leads to extensive use of it, rental laws and laws on the indemnification of tenants discourage investment, lack of credit and insurance schemes, price uncertainty, inadequate

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[11] The assumption of a uniform distribution may be inadequate since $f(M)$ should closely resemble the frequency distribution function of farm sizes. On the other hand, the results are robust to the assumption because of the flatness of the fertilizer response function within the fertilization possibility frontier. The levels of M_1 used in the subsequent integrations are based on the soil fertility levels observed in the trials.

[13] This scheme is not presented as a recommended strategy but only as a way of calculating the cost of lowering fertilizer prices.

[14] Bee de Dagum [2] calculates an export multiplier for Argentina of 3 to 3.5. On the other hand, costs of fertilizer use are underestimated because increases in labor and capital costs that result from its application and from harvesting higher yields are omitted. Since hidden unemployment and overmechanization apparently exist in most small and medium farms in the corn and wheat belts, underestimation would not be serious.

behavioral attitudes toward maximization of profits, and technological change. Although each of these factors may have some relevance, the major limiting factor is the *real unavailability of the fertilizer technology to farmers* in the sense that technical and economic information on its use are almost totally nonexistent. Fertilizer experiments have been few and economic analyses not at all. Worse, the lack of careful assessment of risk, control of soil fertility, and other determinants of fertilizer response has vitiated the interpretation of available data. Since many experiments have been located on large farms which are on the wrong side of the fertilization possibility frontier because the land is used extensively and since land fertility has not previously been taken into account in the analysis of the results, the conclusion has been reached that fertilizer use is indeed of dubious economic worth in Argentina and, eventually, an "insult to the land." In addition, the current unfavorable price situation severely reduces the economic returns from fertilization and consequently leaves little error margins for individual farmers to determine pragmatically the production conditions under which an economic use of fertilizers can be made. More research and extension are needed not only to bring out the potential for fertilizer use, both under present and alternative price policies, but also to shift rightward the fertilization possibility frontier. It is the urgent task of genetic and agronomic research to develop more fertilizer responsive varieties and a package of cultural practices to go along with them. Eventually, as this is most probably the case in the United States, all of the cereal acreage would then lie within the fertilization possibility frontier both because of genetic and agronomic improvements and also because the land would be used more intensively in cereal production. Since the profit function is relatively flat in the organic matter dimension, concern about levels of soil fertility would become of minor importance.

The analysis of cereal fertilization under risk has led to an understanding of the irrationality of the past and present fertilizer price and agricultural research policies of Argentina. As a consequence, this country is losing its international comparative advantages which have been resource based by not participating in the Green Revolution when it could in fact be one of its greatest beneficiaries. The unfortunate truth seems to be that comparative advantages can also be factors of stagnation because they often act as retardants on the needs for technological changes. This is particularly true in countries with weak institutional bases and for the innovations whose research returns cannot be captured and must be generated by the public sector like modern biochemical packages.

References

[1] BARGER, GERALD L., AND H. C. S. THOM, "Evaluation of Drought Hazard," *Agron. J.* 41:519–526, Nov. 1949.

[2] BEE DE DAGUM, ESTELA M., "Le Multiplicateur Dynamique d'Exportation: un Modèle pour l'Argentine," *Economie Appliquee* 22:89–112, 1969.

[3] DE JANVRY, A., "Estancamiento Tecnológico en el Sector Agrícola Argentina: el Caso de la Fertilización del Maíz," *Economica* 17:3–28, 1971.

[4] ———, AND R. KOENIG, "Economía de la Fertilización del Maíz y Trigo en Argentino," Instituto Nacional de la Tecnologia Agropecuaria, Castelar, Argentina, 1971.

[5] FIENUP, DARRELL F., RUSSELL H. BRANNON, AND FRANK A. FENDER, *The Agricultural Development of Argentina. A Policy and Development Perspective*, New York, Frederick A. Praeger, Inc., 1969.

[6] HALTER, A. N., H. O. CARTER, AND J. G. HOCKING, "A Note on the Transcendental Production Function," *J. Farm Econ.* 39:966–974, Nov. 1957.

[7] INTA, unpublished data available at the Agricultural Experiment Station, Marcos Juarez, Argentina.

[8] "La Productividad del Suelo en la Region de Pergamino en Relacion con Factores Ambientales, Tecnologicos, Economicos y Sociales," INTA, Pergamino, May 1964.

[9] PEARSON, KARL, *Tables of the Incomplete Gamma-Function*, London, His Majesty's Stationery Office, 1922.

[10] Tennessee Valley Authority, "Estimated World Fertilizer Production," 1966.

[11] ULVELING, EDWIN F., AND LEHMAN B. FLETCHER, "A Cobb-Douglas Production Function with Variable Returns to Scale," *Am. J. Agr. Econ.* 52:322–326, May 1970.

[12] VERGELIN, C., "Soil and Water Conservation in the Carcarana Watershed: An Economic Study," unpublished Ph.D. thesis, University of Wisconsin, 1971.

[13] WILKS, SAMUEL S., *Mathematical Statistics*, New York, John Wiley & Sons, Inc., 1962.

Profit, Supply, and Factor Demand Functions*

LAWRENCE J. LAU AND PAN A. YOTOPOULOS

The concept of the profit function provides an alternative approach to the analysis of production. First, a brief exposition of the theory of profit function is presented. Then the profit function and the factor demand functions are formulated within the Cobb-Douglas framework. A statistical test is devised for testing the hypothesis of constant returns to scale in all factors on the profit function. As an application, both the profit and the factor demand function are estimated jointly, using data from Indian agriculture.

FOR A GIVEN technology and a given endowment of fixed factors of production, the profit function expresses the maximized profit of a firm as a function of the prices of output and variable inputs and the quantities of the fixed factors of production. The assumptions employed in the formulation of the profit function are: (a) firms are profit maximizing, (b) firms are price takers in both output and variable inputs markets, and (c) the production function is concave in the variable inputs.[1]

The profit function possesses many desirable properties. As McFadden [6] has shown, there exists a one-to-one correspondence between the set of concave production functions and the set of convex profit functions.[2] Every concave production function has a dual which is a convex profit function, and vice versa.[3] Hence, without loss of generality, one can consider only profit functions in the empirical analysis of the behavior of profit-maximizing, price-taking firms.

In the second section is presented a brief exposition of the theory of the profit function demonstrating how the supply function and the factor demand functions for the variable inputs of production may be readily derived from an arbitrary profit function. A similar but more detailed derivation is available in Lau and Yotopoulos [5]. In the third section the profit function and the factor demand functions are formulated within the Cobb-Douglas framework. In the fourth section the implication of the hypothesis of constant returns in all factors on the profit function is examined and how the hypothesis can be tested in the Cobb-Douglas profit function case is explained. Next, in the fifth section, the profit and the factor demand functions are estimated jointly using structural techniques. Note that the estimates so obtained are more efficient than estimates obtained from either function alone. Estimates of the coefficients of the production function as well as labor demand and output supply elasticities with respect to the wage rate, the price of output, and the quantities of the fixed factors of production are derived in the sixth section. Also compared are the estimated production function parameters with those obtained by estimating the production function directly. The empirical application is based on data from Indian agriculture.

Profit Function and Factor Demand Functions

Consider a firm with a production function with the usual neoclassical properties

$$V = F(X_1, \cdots, X_m; Z_1, \cdots, Z_n) \tag{1}$$

where V is output, X_i represents variables inputs, and Z_i represents fixed inputs of production. The profit (defined as current revenues less current total variable costs) can be written

$$P' = pF(X_1, \cdots, X_m; Z_1, \cdots, Z_n) - \sum_{i=1}^{m} c_i' X_i \tag{2}$$

where P' is profit, p is the unit price of output,

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[1] This implies, among other things, that there exist decreasing returns to scale in the variable inputs taken altogether.

[2] There are additional regularity conditions on the production and profit functions which are spelled out in detail in McFadden [6]. Since we are interested in the empirical application of profit functions, we will not be concerned with the finer details. It suffices to say that almost all continuous production functions in current use which are concave will give rise to a well-behaved profit function. Similar duality results between production and cost functions have been derived by Shephard [9] and Uzawa [10].

[3] We rule out constant returns to scale in the variable factors, which, as is well known, would lead to indeterminate output and input levels. See Lau [4].

LAWRENCE J. LAU *is assistant professor of economics and* PAN A. YOTOPOULOS *is an associate professor in the Food Research Institute, Stanford University.*

and c_i' is the unit price of the ith variable input.

The marginal productivity conditions for a profit-maximizing firm are

$$(3) \quad p\frac{\partial F(X;Z)}{\partial X_i} = c_i', \qquad i = 1, \cdots, m.$$

By defining $c_i \equiv c_i'/p$ as the normalized price of the ith input, equation (3) is written as

$$(4) \qquad \frac{\partial F}{\partial X_i} = c_i, \qquad i = 1, \cdots, m.$$

By similar deflation (2) can be rewritten as (5) where P is defined as the "Unit-Output-Price" profit, or *UOP profit*

$$(5) \qquad P = \frac{P'}{p} = F(X_1, \cdots, X_m; Z_1, \cdots, Z_n) - \sum_{i=1}^{m} c_i X_i.$$

Equation (4) may be solved for the optimal quantities of variable inputs, denoted X_i^*'s, as functions of the normalized prices of the variable inputs and of the quantities of the fixed inputs,

$$(6) \qquad X_i^* = f_i(c, Z), \qquad i = 1, \cdots, m.$$

where c and Z without subscripts denote vectors.

By substituting (6) into (2) *profit function*[4] is obtained

$$(7) \qquad \Pi^{*\prime} = p\left(F(X_1^*, \cdots, X_m^*; Z_1, \cdots, Z_n) - \sum_{i=1}^{m} c_i X_i^*\right).$$

The profit function gives the *maximized* value of the profit for each set of values $\{p, c', Z\}$. Observe that the term within the large parentheses on the right-hand side of (7) is a function only of c and Z. Hence,

$$(8) \quad \Pi^{*\prime} = pG^*(c_1, \cdots, c_m; Z_1, \cdots, Z_n).$$

The *UOP profit function* is therefore given by

$$(9) \quad \Pi^* = \frac{\Pi^{*\prime}}{p} = G^*(c_1, \cdots, c_m; Z_1, \cdots, Z_n).$$

The UOP profit function Π^* is employed because it is easier to work with than $\Pi^{*\prime}$. It is evident that given Π^* one can always find $\Pi^{*\prime}$, and vice versa. Furthermore, on the basis of *a priori* theoretical considerations it is known that the UOP profit function is decreasing and convex in the normalized prices of variable inputs and increasing in quantities of fixed inputs. It follows also that the UOP profit function is increasing in the money price of the output.[5]

A set of dual transformation relations connects the production function and the profit function.[6] The most important one, from the point of view of the application here, is what is sometimes referred to as the Shephard's [9] Lemma, namely,

$$(10) \quad X_i^* = -\frac{\partial \Pi^*(c, Z)}{\partial c_i}, \quad i = 1, \cdots, m,$$

$$(11) \quad V^* = \Pi^*(c, Z) - \sum_{i=1}^{m} \frac{\partial \Pi^*(c, Z)}{\partial c_i} c_i,$$

where V^* is the supply function.[7]

At this point the advantages of working with the UOP profit function instead of the traditional production function should be emphasized. First, through equations (10) and (11), the Shephard's Lemma makes it possible to derive the supply function, V^*, and the factor demand functions, X_i^*'s, directly from an *arbitrary* UOP profit function, which is decreasing and convex in the normalized prices of the variable inputs and increasing in the fixed inputs, *without* an explicit specification of the corresponding production function (and hence without solving equation (4)). This provides a great deal of flexibility in empirical analysis.[8] Second, by starting from a profit function, it is assured by duality that the resulting system of supply and factor demand functions is obtainable from profit maximization of a firm with a production function concave in the variable inputs subject to given fixed inputs and under competitive markets. Third, the profit function, the supply function, and the derived demand functions so

[4] This is sometimes called the *partial* profit function because some inputs are held fixed.

[5] See Lau [4] for a proof of these results.

[6] These relations are given and proved in McFadden [6] and Lau [4].

[7] Because $\Pi^*(c, Z)$ is decreasing in c, $\partial\Pi^*(c, Z)/\partial c$ will always be negative. These derivatives equal $\partial\Pi^{*\prime}(c, Z)/\partial c'$.

[8] For some possible functional forms for the profit function, see McFadden [6] and Lau [4].

obtained may be *explicitly* written as functions of variables that are normally considered to be determined independently of the firm's behavior. Econometrically, this implies that these variables are exogenous variables. By estimating these functions directly the problem of simultaneous equations bias to the extent that it is present can be avoided.

From the point of view of empirical implementation, the UOP profit function (or alternatively, the supply function) and the factor demand functions should be estimated jointly, since there will be parameters common to both the UOP profit function and the derived demand functions. Hence, the restriction that the common parameters are equal should be imposed. In addition, to take into account the possibility that the errors in different equations may be correlated, a method similar to that developed by Zellner [14] should be employed. This will be further elaborated in the empirical analysis section.

The Cobb-Douglas Case

A Cobb-Douglas production function with decreasing returns in variable inputs is given by

$$V = A \prod_{i=1}^{m} X_i^{\alpha_i} \prod_{i=1}^{n} Z_i^{\beta_i}, \tag{12}$$

where $\mu \equiv \sum_{i=1}^{m} \alpha_i < 1.$

The UOP profit function for this Cobb-Douglas production function is

$$\Pi^* = A^{(1-\mu)^{-1}}(1-\mu) \cdot \left(\prod_{i=1}^{m} \left(\frac{c_i}{\alpha_i}\right)^{-\alpha_i(1-\mu)^{-1}} \right) \cdot \left(\prod_{i=1}^{n} Z_i^{\beta_i(1-\mu)^{-1}} \right). \tag{13}$$

Taking natural logarithms of (13),

$$\ln \Pi^* = \ln A^* + \sum_{i=1}^{m} \alpha_i^* \ln c_i + \sum_{i=1}^{n} \beta_i^* \ln Z_i \tag{14}$$

where

$$A^* \equiv A^{(1-\mu)^{-1}}(1-\mu) \left(\prod_{i=1}^{m} \alpha_i^{\alpha_i(1-\mu)^{-1}} \right)$$

$$\alpha_i^* \equiv -\alpha_i(1-\mu)^{-1} < 0 \qquad i = 1, \cdots, m$$

$$\beta_i^* \equiv \beta_i(1-\mu)^{-1} > 0^{9} \qquad i = 1, \cdots, n.$$

The derived demand functions are given by (10), i.e.,

$$X_i^* = -\frac{\partial \Pi^*}{\partial c_i} \qquad i = 1, \cdots, m. \tag{15}$$

Multiplying both sides of (15) by $-c_i/\Pi^*$

$$-\frac{c_i X_i^*}{\Pi^*} = \frac{\partial \ln \Pi^*}{\partial \ln c_i} \qquad i = 1, \cdots, m \tag{16}$$

which for the Cobb-Douglas profit function becomes

$$-\frac{c_i X_i^*}{\Pi^*} = \alpha_i^* \qquad i = 1, \cdots, m. \tag{17}$$

Equations (14) and (17) are the estimating equations for the present study. Note that the α_i^*'s appear in both the UOP profit function and the ith factor demand function.

Profit function and constant returns to scale

Given a production function

$$V = F(X_1, \cdots, X_m; Z_1, \cdots, Z_n)$$

which is homogeneous of degree k, then, from Euler's Theorem,

$$\sum_{i=1}^{m} \frac{\partial F}{\partial X_i} X_i + \sum_{i=1}^{n} \frac{\partial F}{\partial Z_i} Z_i = kF. \tag{18}$$

For a profit-maximizing firm,

$$\frac{\partial F}{\partial X_i} = c_i \qquad i = 1, \cdots, m;$$

from (10),

$$X_i^* = \frac{-\partial \Pi^*}{\partial c_i} \qquad i = 1, \cdots, m;$$

from (11),

$$V^* = F = \Pi^* - \sum_{i=1}^{m} \frac{\partial \Pi^*}{\partial c_i} c_i;$$

and by differentiating (5),

$$\frac{\partial F}{\partial Z_i} = \frac{\partial \Pi^*}{\partial Z_i} \qquad i = 1, \cdots, n.$$

[9] Note that these elasticities may be large if the degree of returns in the variable inputs is close to unity.

Substituting these results into (18) for the profit-maximizing firm gives

$$-\sum_{i=1}^{m} c_i \frac{\partial \Pi^*}{\partial c_i} + \sum_{i=1}^{n} \frac{\partial \Pi^*}{\partial Z_i} Z_i = k\left(\Pi^* - \sum_{i=1}^{m} \frac{\partial \Pi^*}{\partial c_i} c_i\right)$$

or

$$(19)\quad \frac{(k-1)}{k} \sum_{i=1}^{m} \frac{c_i \partial \Pi^*}{\partial c_i} + \frac{1}{k} \sum_{i=1}^{n} \frac{\partial \Pi^*}{\partial Z_i} Z_i = \Pi^*.$$

In other words, Π^* is an almost homogeneous function of degrees $(k-1)/k$ and $1/k$ in variable input prices and quantities of fixed factors, respectively.[10] The above condition is also sufficient for homogeneity of degree k of the production function as all the steps may be reversed.

For the case of a Cobb-Douglas profit function, the condition reduces to

$$\frac{(k-1)}{k} \sum_{i=1}^{m} \alpha_i^* + \frac{1}{k} \sum_{i=1}^{n} \beta_i^* = 1,$$

or alternatively,

$$\sum_{i=1}^{n} \beta_i^* = k - (k-1) \sum_{i=1}^{m} \alpha_i^*.$$

Note that $\sum_{i=1}^{m} \alpha_i^* < 0$ by the monotonicity conditions on the profit function. Hence, if $k>1$ (increasing returns), $\sum_{i=1}^{n} \beta_i^* > 1$. If $k=1$ (constant returns), $\sum_{i=1}^{n} \beta_i^* = 1$. If $k<1$ (decreasing returns), $\sum_{i=1}^{n} \beta_i^* < 1$.[11] A test of the hypothesis of constant returns *in all inputs* in the Cobb-Douglas case then becomes a test of the hypothesis $\sum_{i=1}^{n} \beta_i^* = 1$, where the β_i^*'s are the elasticities of the profit function with respect to the fixed factors of production.

Empirical Analysis

In this section data from the *Farm Management Studies* of the Indian Ministry of Food and Agriculture [16] are used to estimate jointly the UOP profit function and the labor demand function. The definition of variables is identical with those in Lau and Yotopoulos [5].

A CES production function has been fitted directly with nonlinear methods. The value of the elasticity of substitution was found to be not significantly different from one.[12] The authors therefore conclude it is appropriate to analyze the data of the *Studies* within the Cobb-Douglas framework.

Given the data for application, with labor as the variable factor of production and capital and land as the fixed factors, the profit function (14) and the labor demand function (17) are written

$$(20)\quad \ln \Pi^* = \ln A^* + \alpha_1^* \ln w + \beta_1^* \ln K + \beta_2^* \ln T$$

$$(21)\quad -\frac{wL}{\Pi^*} = \alpha_1^*$$

where Π^* is UOP profit (total revenue less total variable cost, divided by the price of output), w is normalized wage rate, K is interest on fixed capital, T is cultivable land, and L is quantity of labor employed. A problem arises at this point. The formulation of the UOP profit and labor demand functions is in terms of normalized prices. However, only money profits and wage rates are available because the data on prices of output are rather poor. Fortunately, (20) may be rewritten

$$\begin{aligned}\ln \Pi^* &= \ln \Pi^{*\prime} - \ln p \\ &= \ln A^* + \alpha_1^* \ln w' - \alpha_1^* \ln p \\ &\quad + \beta_1^* \ln K + \beta_2^* \ln T\end{aligned}$$

or

$$\begin{aligned}\ln \Pi^{*\prime} &= \ln A^* + (1-\alpha_1^*) \ln p + \alpha_1^* \ln w' \\ &\quad + \beta_1^* \ln K + \beta_2^* \ln T\end{aligned}$$

where $\Pi^{*\prime}$ is money profit in rupees, w' is the money wage rate in rupees per day, and p is the price of the output in rupees. If the prices of output differ only across states, then state dummy variables can be inserted to capture the effect of differences due to $(\ln A^* + (1-\alpha_1^*) \ln p)$. This also allows interstate differences in the efficiency parameter in A^*. Observe that (21) holds independently of the price of output

$$-\frac{wL}{\Pi^*} = -\frac{w'L}{\Pi^{*\prime}} = \alpha_1^*.$$

Hence, the final estimating equations consist of

$$(22)\quad \ln \Pi^{*\prime} = \alpha_0 + \sum_{i=1}^{4} \delta_i^* D_i + \alpha_1^* \ln w' + \beta_1^* \ln K + \beta_2^* \ln T$$

[10] For a discussion of almost homogeneous functions in the economic context, see Lau [4].

[11] $k>0$ for a production function.

[12] See Yotopoulos, Lau, and Somel [13].

$$(23) \quad -\frac{w'L}{\Pi^{*'}} = \alpha_1^*.$$

where

- $\Pi^{*'}$ is profit (current revenue less current variable costs) in rupees per farm.
- w' is money wage rate in rupees per day.
- D_i is regional dummy variable with D_1, D_2, D_3, D_4 taking the value of one for only West Bengal, Madras, Madhya Pradesh, and Uttar Pradesh, respectively.
- L is labor in days per year per farm.
- K is interest on fixed capital per farm.
- T is cultivable land in acres per farm.

Given the assumption of profit-maximizing and price-taking firms with production functions concave in the variable inputs and the short-run fixity of the quantities of capital and land, the farm's decision variables are the quantities of output and labor input. The values of the prices of output and variable inputs and the quantities of the fixed inputs are predetermined and not subject to change by any action of the farm in the short run. Consequently, output and labor input are the jointly dependent variables, and the prices of output and variable inputs and the quantities of fixed inputs are the predetermined variables in the model. Because of the profit identity, namely, that profit is equal to current revenue less current variable costs, an alternative set of jointly dependent variables consists of profits and total labor costs. It is clear that given the predetermined variables, there is a one-to-one and onto correspondence between profits and total labor costs and the quantities of output and labor input. Thus, in (22) and (23), the variables on the left-hand side are the jointly dependent variables and those on the right-hand side include only the predetermined variables.

Under these conditions, ordinary least squares applied to each equation separately will be consistent. However, these estimates in general will be inefficient because that α_1^* appears in both (22) and (23) has been ignored. A natural and more efficient approach will be to estimate (22) and (23) jointly, imposing the condition that the two α_1^*'s are equal. Not much is known about how disturbance terms in general should be introduced into economic relationships, although Hoch and Mundlak [3, 7] and subsequently Zellner, Kmenta, and Drèze [15] have proposed one possible assumption that is workable in the Cobb-Douglas case. Here the usual, and admittedly *ad hoc*, practice of assuming an additive error with zero expectation and finite variance for each of the equations (22) and (23) is followed. Nerlove [8] in his pioneering study of cost functions derives an additive error to the natural logarithm of the cost function. The same can be done here for profit function, using similar assumptions, namely, that farms maximize profits subject to unknown exogenous disturbances. The additive error in the second equation may arise from differential abilities to maximize profits or divergence between expected and realized prices. A similar stochastic specification is employed by Arrow, Chenery, Minhas, and Solow [1] in their estimating equation for the elasticity of substitution. For the same farm, the covariance of the errors of the two equations is permitted to be nonzero. However, the covariances of the errors of either equation corresponding to different farms are assumed to be identically zero. Given this specification of errors, it is apparent that Zellner's [14] method, imposing known constraints on the coefficients in the equations, provides an asymptotically efficient method of estimation.

Equations (22) and (23) are first estimated jointly imposing the condition that α_1^* is identical from both equations. These results as well as those of single equation ordinary least squares and of unconstrained Zellner's method are presented in Table 1. Note that in accordance with *a priori* economic theory the UOP profit function is not only decreasing in w' but also convex. The second derivative of the UOP profit function with respect to the wage rate is

$$\begin{aligned}\frac{\partial^2\Pi^*}{\partial w^2} &= \frac{\alpha_1^{*2}\Pi^*}{w^2} - \frac{\alpha_1^*\Pi^*}{w^2} \\ &= \alpha_1^*(\alpha_1^* - 1)\,\frac{\Pi^*}{w^2} \\ &= -1.156\,(-2.156)\,\frac{\Pi^*}{w^2} \geq 0\end{aligned}$$

as $\Pi^{*'} > 0$ for the entire sample. The positive coefficient of land is also consistent with *a priori* notions. The wrong coefficient of capital can probably be attributed to an unavoidable misspecification of this variable.[13] This however is

[13] By defining capital as interest on fixed capital per farm, the assumption is implicitly made that the service flow of capital, which is the appropriate input in production analysis, is proportional to the capital stock. This amounts

Table 1. Joint estimation of Cobb-Douglas profit function and labor demand function

Function	Parameter	Estimated Coefficients*			
		Single equation ordinary least squares	Zellner's method with restrictions		
			Unrestricted	1 Restriction $\alpha_1^*=\alpha_1^*$	2 Restrictions $\alpha_1^*=\alpha_1^*$ $\beta_1^*+\beta_2^*=1$
UOP profit function	$\ln A^*$	4.888 (.499)	4.440 (.441)	4.470 (0.300)	4.415 (0.194)
	δ_1^*	1.535 (.515)	(0.904) (0.455)	0.829 (0.435)	0.776 (0.377)
	δ_2^*	−1.658 (1.191)	−0.900 (1.051)	−1.050 (0.603)	−1.133 (0.497)
	δ_3^*	−0.712 (.453)	−0.275 (0.400)	−0.307 (0.238)	−0.310 (0.238)
	δ_4^*	0.103 (.667)	0.066 (0.589)	−0.040 (0.483)	−0.111 (0.383)
	α_1^*	−2.368 (1.123)	−1.071 (0.992)	−1.156 (0.379)	−1.166 (0.376)
	$_1^*$	−0.573 (0.258)	−0.303 (0.227)	−0.263 (0.221)	−0.224 (0.153)
	β_2^*	1.581 (0.199)	1.278 (0.176)	1.241 (0.168)	1.224 (0.153)
Labor demand function	α_1^*	−1.209 (.412)	−1.209 (0.412)	−1.156 (0.379)	−1.166 (0.376)

* Numbers in parentheses are asymptotic standard errors.

not especially disturbing since the coefficient is statistically insignificant. Finally, one may note the marked improvement in the coefficients that results from the constrained joint estimation of both functions.

An F-statistic is computed to test the null hypothesis that the α_1^*'s from the two equations are indeed equal. For

$$H_o: \quad \alpha_1^* = \alpha_1^*$$

$$F(1, 59) = 0.02 < F_{0.05}(1, 59) = 4.0.$$

The null hypothesis cannot be rejected at the 5 percent significance level. The equality hypothesis is therefore maintained for subsequent analysis.

Subject to the equality hypothesis, the hypothesis that the model has no explanatory power is tested, i.e.,

$$H_o: \quad \alpha_1^* = 0$$
$$\beta_1^* = 0$$
$$\beta_2^* = 0.$$

The computed and critical F-values are

$$F(3, 60) = 89.2 > F_{0.05}(3, 60) = 2.76.$$

to misspecification of capital and leads to biased coefficients as shown by Yotopoulos [11, 12].

Therefore, the hypothesis that the model has no explanatory power is rejected.

Third, again subject to the equality hypothesis, the hypothesis of constant returns to scale through the coefficients of the fixed factors in the profit function is tested.

$$H_o: \quad \beta_1^* + \beta_2^* = 1.$$

$$F(1, 60) = 0.05 < F_{0.05}(1, 60) = 4.0.$$

The hypothesis of constant returns cannot be rejected.

On the basis of these findings estimation of the two functions can be progressed by adding to the restriction on the equality of the labor coefficients, $\alpha_1^* = \alpha_1^*$, the assumption of constant returns to scale, i.e., $\beta_1^* + \beta_2^* = 1$. The results of this constrained estimation with two restrictions are presented in the last column of Table 1. This is the final set of estimates and will be used in further analysis.

Implications of the Analysis

The results in Table 1 may be utilized in the derivation of a number of estimates of crucial importance in the applications of economic theory; namely, estimates of labor demand elasticities and of output supply elasticities with respect to wage rate, price of output, and quantities of fixed factors of production.

The estimates of Table 1 imply, by (14), estimates for the input elasticities of the production function. These are presented in Table 2. The main advantage of obtaining the input elasticities indirectly from the profit function is statistical consistency. Estimates of these

Table 2. Estimates of the input elasticities of the production function

Parameter	Indirect estimates*		Direct production function estimate
	1 Restriction $\alpha_1^* = \alpha_1^*$	2 Restrictions $\alpha_1^* = \alpha_1^*$ $\beta_1^* + \beta_2^* = 1$	
Labor α_1	0.536	0.538	0.767
Capital β_1	−0.122	−0.103	−0.059
Land β_2	0.576	0.565	0.371
Sum of Elasticities $(\alpha_1+\beta_1+\beta_2)$	0.990	1.000	1.079

* The indirect estimates are computed from the identities in (14). They are the coefficients of the production function.

same elasticities obtained directly from the production function by ordinary least squares are in general inconsistent because of the existence of simultaneous equations bias. For the purpose of comparison, the estimates of the same parameters obtained directly from the production function are also listed.

From (23) the labor demand equation is written as

$$L = -\frac{\alpha_1{}^*\Pi^{*\prime}}{w'}$$

or

$$\ln L = \ln(-\alpha_1{}^*) + \ln \Pi^{*\prime} - \ln w'.$$

Hence, the labor demand elasticities with respect to the wage rate and land—the two variables that have statistically significant coefficients—are given by

$$\text{(24)} \qquad \frac{\partial \ln L}{\partial \ln w'} = \frac{\partial \ln \Pi^{*\prime}}{\partial \ln w'} - 1 = \alpha_1{}^* - 1 = -2.166$$

$$\text{(25)} \qquad \frac{\partial \ln L}{\partial \ln T} = \frac{\partial \ln \Pi^{*\prime}}{\partial \ln T} = \beta_2{}^* = 1.224$$

The labor demand elasticity with respect to the price of output is given by

$$\text{(26)} \qquad \frac{\partial \ln L}{\partial \ln p} = \frac{\partial \ln L}{\partial \ln w}\,\frac{\partial \ln w}{\partial \ln p} = 2.166.$$

It is apparent that labor has a negative own-price elasticity of demand, as predicted by economic theory. Moreover, the absolute value of the elasticity is greater than one, indicating a rather elastic response of labor utilization to wage rate. On the other hand, labor demand also responds positively to increases in the endowments of land as well as to increases in the price of output. These findings have obvious partial equilibrium implications about the labor absorptive capacity of Indian agriculture.

It is interesting to calculate the output responses of the firm. Output is given by

$$\text{(27)} \qquad V = \Pi^* + wL = \Pi^*(1 - \alpha_1{}^*)$$

$$\text{(28)} \qquad \frac{\partial \ln V}{\partial \ln w} = \frac{\partial \ln \Pi^*}{\partial \ln w} = \alpha_1{}^* = -1.166.$$

Hence, output is decreased with an increase in the normalized wage rate and the value of the coefficient implies somewhat elastic response. Similarly,

$$\text{(29)} \qquad \frac{\partial \ln V}{\partial \ln p} = \frac{\partial \ln V}{\partial \ln w}\,\frac{\partial \ln w}{\partial \ln p} = 1.166,$$

that is, the own-price supply elasticity is positive, statistically significant, and greater than one. This finding bears directly on the controversy about price responsiveness in Indian agriculture.[14]

Differentiating output in (27) with respect to land, the reduced form elasticity is obtained

$$\text{(30)} \qquad \frac{\partial \ln V}{\partial \ln T} = \frac{\partial \ln \Pi^*}{\partial \ln T} = \beta_2{}^* = 1.224.$$

The interpretation of this reduced form elasticity is that it measures the output response of a price-taking, profit-maximizing farm household with respect to an exogenous increase in the quantity of land, holding normalized prices of the variable inputs (the wage rate in this case) constant. Such reduced form elasticities, therefore, reflect the *mutatis mutandis* effect in the expansion of capital (land) as opposed to the production function elasticities which measure the *ceteris paribus* (i.e., holding the quantities of other factors constant) effect of an increase in capital (land). Reduced form elasticities are especially relevant for purposes of prediction and for formulating government policy. A given increase in the quantity of land will shift upwards the marginal productivity curve of labor (as well as that of the other factors of production). As a result the profit-maximizing firm will employ more labor than before. Under these conditions elasticities that purport to holding the quantity of other factors of production constant are rather useless. Instead, the *mutatis mutandis* elasticities should be of more interest. This is especially the case with the analysis of farm household behavior in which the wage rate is usually considered determined exogenously by the industrial sector.

Summary

In this paper it is demonstrated how one can

[14] For a summary of this controversy see Bhagwati and Chakravarty [2].

derive supply and factor demand functions from the profit function in general and, furthermore, how the empirical estimation may be implemented. This framework was applied by estimating jointly the profit function and the labor demand function for Indian agriculture. The joint estimation utilizes *a priori* theoretical information that is inherent in the tool of the profit function. In this analysis the model of short-run profit maximization is consistent with the observed behavior of the firm. A number of estimates which generally agree with *a priori* notions and with economic theory are derived from the profit function model. They are the coefficients of the production function as well as the labor demand and output supply elasticities with respect to wage rate, price of output, and the quantity of the fixed factor of production (land).

References

[1] Arrow, K. J., H. B. Chenery, B. S. Minhas, and R. M. Solow, "Capital-Labor Substitution and Economic Efficiency," *Rev. Econ. & Stat.* 43:225–250, Aug. 1961.

[2] Bhagwati, Jagdish S., and Sukhamoy Chakravarty, "Contributions to Indian Economic Analysis: A Survey," *Am. Econ. Rev.* 59(Suppl):1–73, Sept. 1969.

[3] Hoch, Irving, "Simultaneous Equation Bias in the Context of the Cobb-Douglas Production Function," *Econometrica* 26:566–578, Oct. 1958.

[4] Lau, L. J., "Applications of Profit Functions," in *An Econometric Approach to Production Theory*, ed. D. L. McFadden, to be published, Amsterdam, North-Holland Pub. Co., 1971.

[5] Lau, Lawrence J., and Pan A. Yotopoulos, "A Test for Relative Efficiency and Application to Indian Agriculture," *Am. Econ. Rev.* 61:94–109, March 1971.

[6] McFadden, D. L., "Cost, Revenue, and Profit Functions," in *An Econometric Approach to Production Theory*, ed. D. L. McFadden, to be published, Amsterdam, North-Holland Pub. Co., 1971.

[7] Mundlak, Yair, and Irving Hoch, "Consequences of Alternative Specifications in Estimation of Cobb-Douglas Production Functions," *Econometrica* 33:814–828, Oct. 1965.

[8] Nerlove, Marc, "Returns to Scale in Electricity Supply," in *Measurement in Economics: Studies in Mathematical Economics and Econometrics in Memory of Yehuda Grunfeld*, ed. Carl F. Christ, *et al.*, Stanford, Stanford University Press, 1963, pp. 167–198.

[9] Shephard, R. W., *Cost and Production Functions* Princeton, Princeton University Press, 1953.

[10] Uzawa, Hirofumi, "Duality Principles in the Theory of Cost and Production," *Internat. Econ. Rev.* 5:216–220, May 1964.

[11] Yotopoulos, P. A., *Allocative Efficiency in Economic Development: A Cross Section Analysis of Epirus Farming*, Athens, Center of Planning and Economic Research, 1968.

[12] Yotopoulos, Pan A., "From Stock to Flow Capital Inputs for Agricultural Production Functions: A Microanalytic Approach," *J. Farm Econ.* 49:476–491 May 1967.

[13] Yotopoulos, P. A., L. J. Lau, and K. Somel, "Labor Intensity and Relative Efficiency in Indian Agriculture," *Food Res. Inst. Agr. Econ., Trade, Develop* 9:43–55, 1970.

[14] Zellner, Arnold, "An Efficient Method of Estimating Seemingly Unrelated Regressions and Tests for Aggregation Bias," *J. Am. Stat. Assoc.* 57:348–368 June 1962.

[15] Zellner, A., J. Kmenta, and J. Drèze, "Specification and Estimation of Cobb-Douglas Production Function Models," *Econometrica* 34:784–795, Oct. 1966.

[16] Government of India, Ministry of Food and Agriculture, *Studies in the Economics of Farm Management* Delhi, 1957–62; reports for the year 1955–56—Madras Punjab, Uttar Pradesh, West Bengal; report for the year 1956–57—Madhya Pradesh.

Rice Policy in Japan's Economic Development*

Yujiro Hayami

Until only a decade ago, Japan's rice policy had been primarily designed to procure "cheap" rice for the industrial population from domestic and colonial producers. For the promotion of industrialization and economic growth the price of rice, the principal wage good, had been kept low to prevent the rise in the wage rate of urban industrial workers. The shift from the traditional cheap rice policy to a recent policy of high price supports is due to the decline in the role of rice as a wage good. The rapid rise in per capita income and the dramatic transformation of Japan's industrial structure contributed to the policy change.

Japan's rice policy in the past decade represents a major violation of the theory of international comparative advantage. The price of domestic rice in the late 1960's was more than double the import price due to continuous increases in the government supported price of Japanese-produced rice.

Such high level price support was a heavy burden on the national budget as evidenced by the 1971 budget in which government expenditures for rice support, including the deficit of the Food Control Special Account and expenses for retirement and diversion of paddy fields, amounted to 463 billion *yen* (1.3 billion U.S. dollars). This total accounted for 50 percent of the agriculture and forestry budget and nearly 5 percent of the total national budget (Table 1). Concomitantly, this price support hindered the shift of agricultural resources from rice production to other products of rising demand such as livestock and vegetables. It also discouraged the out-migration of farm labor to non-agriculture when labor shortage became a permanent feature of the economy.

The purpose of this study is to analyze this current policy issue in the historical perspective of Japan's modern economic growth since the Meiji Restoration (1868).[1] Although this may appear to be a recent problem, the current issue of rice control and price support can best be understood by comparing long-term changes in the role of rice as a critical wage good to changes in industrial structure and per capita income. Interaction of rice policy and economic growth in the history of Japan also provides information on the strategy of economic development

Table 1. Deficit of the food control program in relation to the total national budget and the budget for agriculture and forestry of the central government, 1951–71*

Year	Balance of the Food Control Special Account	Ratio of deficit of the Food Control Account to: Agriculture & forestry budget	Total budget
	billion *yen*	percent	
1951	3.8	− 3.6	−0.5
52	− 14.0	9.7	1.5
53	− 20.6	12.1	2.0
54	− 13.0	11.6	1.3
55	− 0.3	0.3	0
56	− 16.0	17.5	1.5
57	− 6.7	5.5	0.6
58	− 2.1	2.0	0.2
59	− 10.2	8.8	0.7
60	− 28.5	17.1	1.6
61	− 58.6	25.5	2.8
62	− 62.5	24.4	2.4
63	− 78.6	26.3	2.6
64	−126.9	36.4	3.8
65	−128.1	31.6	3.3
66	−213.9	38.5	4.8
67	−248.8	40.3	4.8
68	−278.2	40.6	4.7
69	−344.1	41.6	5.0
	(356.6)[a]	(43.1)	(5.1)
70	−346.2[b]	34.9	4.2
	(456.4)[a]	(46.0)	(5.6)
71	−292.3[b]	25.5	2.6
	(476.3)[a]	(49.3)	(4.9)

[a] Numbers in parentheses are the budget for the deficit from the food control program including the budget for retirement and diversion of paddy field area.
[b] Balance of rice and *mugi* control only.
* Data provided by the Research Section, Food Board, and the Budget Section, Minister's Office, Ministry of Agriculture and Forestry.

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[1] For an excellent review of the history of rice policy in relation to economic growth, see Mochida [17, 18]. For factual descriptions of rice policies, see Ogura [21, pp. 149–210].

Yujiro Hayami *is associate professor of economics at Tokyo Metropolitan University, Meguro-Ku, Tokyo.*

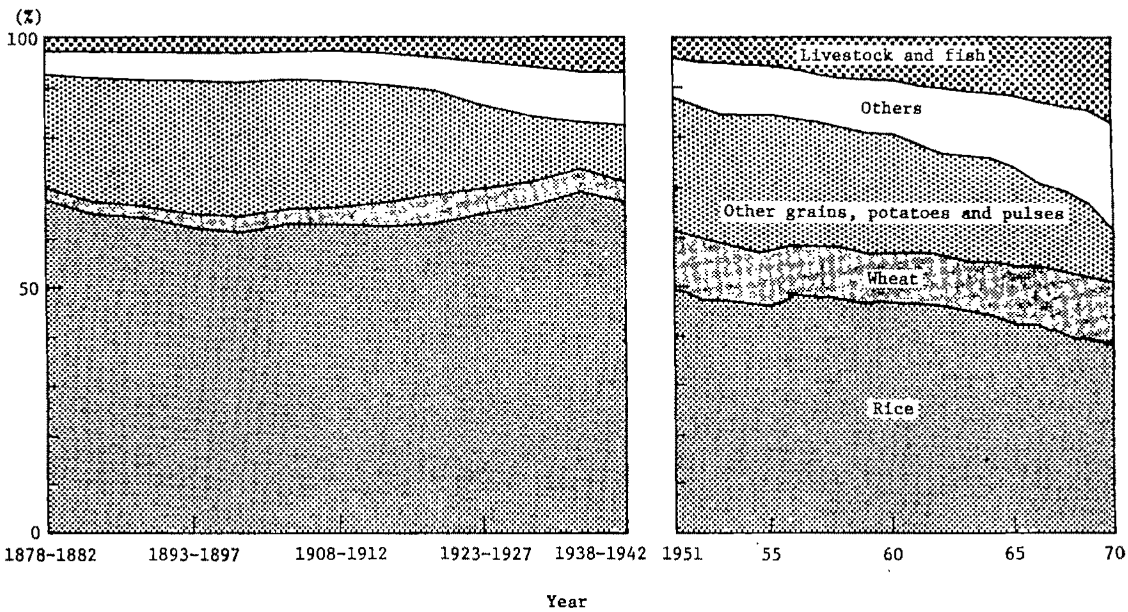

Figure 1. Changes in the shares of various food items in the total calorie intake of the Japanese, 1878–1942 quinquennial data and 1951–1969 annual data
Sources: JMAF [11] and Yamada and Hayami [24]

that would be valuable to countries in South and Southeast Asia which are now exploring conversion of the production potential of rice and other food cereals, increased by recent technical advancements, into overall economic growth.

Role of Rice as a Wage Good

Industrialization and economic growth are conditioned by the availability of agricultural surpluses, especially the surplus of basic food staples as wage goods for industrial workers ("Surplus" is defined here as the difference between production and consumption by producers.). In the classical model of economic development from Ricardo to Arthur Lewis [16] and Fei and Ranis [1], capital returns (hence, capital formation and economic growth) critically depend on the elastic supply of labor to industry, which in turn depends on the elastic supply of food to the urban sector.[2] Food may be imported from abroad, but this implies a drain on foreign exchange needed for the import of capital goods and technical know-how critical for development.

Within less than a century, Japan has changed from a predominantly rural state to one of the world's highly industrialized nations. In the course of this industrialization rice has been the critical wage good. Figure 1 shows rice as the source for more than 60 percent of the total caloric intake of the Japanese before World War II. It was only in the late 1960's that the share of rice in the total caloric intake dropped below 40 percent.[3] The share of rice in the consumption expenditure of urban blue collar workers continued to be as high as 30 percent until 1930. Despite rapid growth in per capita income, the share of rice in the consumption expenditure of urban worker households did not drop below 10 percent before 1960 (Table 2).

It was critical for the industrial development of Japan before 1960 and particularly before 1920 when labor-intensive light industries (such as textiles) predominated, especially in the manufacturing of export goods, to supply cheap rice to industrial workers to keep their living costs and wages low.

When she opened her doors to foreign countries shortly before the Meiji Restoration, Japan was in real danger of colonialization by the western powers. The national slogan then was to "build wealthy nation and strong army"

[2] Such questionable restrictive assumptions as "surplus labor at zero marginal productivity" and "institutional wage rate" are unnecessary for the present discussion.

[3] Decline in the share of rice from before to after World War II is explained by an increase in wheat consumption. The wheat-eating habit was developed during the period of rice shortage through school lunch programs, etc.

(*Fukoku Kyohei*). To attain this goal it was considered necessary to "develop industries and promote enterprises" (*Shokusan Kogyo*).

Assuming industrial development was a national goal, it is plausible that the price support policy was designed to secure the supply of rice, which could prevent the rise in the cost of living of urban workers. Figure 2 plots the price of rice since 1880. The current (undeflated) price shows a clear upward trend with big jumps during the two World Wars (real line). A remarkable fact is that the price of rice deflated by the general price index (dotted line) remained at about the same level from the early Meiji period up to 1960. However, it was subject to considerable fluctuation because of business cycles (among the most pronounced were downswings in the mid-1880's due to the so-called "Matsukata Deflation"[4] and in the early 1930's due to the World Depression and an upswing brought on by the World War I boom).

In relation to the long-term trend in the deflated price of rice, it is clear the rapid rise in rice prices during the 1960's was an entirely new phenomenon in the modern history of Japan. The trade of rice with other commodities clearly deviated from a boundary which was stable from 1880 to 1960.

From these observations it is possible to postulate the following hypotheses concerning interactions between rice policy and economic growth in Japan.

First, from the beginning of the Meiji Period to 1960, institutions and policies were, intentionally or not, designed to prevent the price of rice (relative to the general price index) from moving outside a stable boundary. Prevention of an increase in rice prices above a certain upper boundary was motivated to facilitate industrial development by keeping the cost of the critical wage good below a certain tolerable level in an economy dominated by labor-intensive industries.

Policy to keep rice prices above a lower boundary was naturally motivated to prevent the living standards of a majority of the farm population from declining below a subsistence level and thus causing social disorders. More positively it was intended to preserve the basis of agricultural reproduction and to keep alive farmers' incentive to increase rice production and productivity. Decline in the production of rice and hence, in the rice self-sufficiency, had to be avoided because it implied a drain on foreign exchange that was critical for industrial development.

Second, the unprecedented spurt of industrial development after the mid-1950's transformed the industrial structure of Japan and increased urban wages dramatically. Strength of Japanese industry in international competition no longer rested on "cheap labor." In response to wage and income increases, the share of rice in urban workers' consumption expenditures declined. Once a critical requirement for industrial development, rice as a wage good drastically decreased in importance. The Japanese economy reached the stage in which a rise in rice prices could be tolerated.

Continuous increases in rice prices during the 1960's were the result of extremely strong political pressure from farmers, requesting income and living level parity with urban workers. If rice had remained a critical wage good, it is inconceivable that political pressure of farm organizations could have brought about a rise

Table 2. Share of the expenditure for rice in total consumption expenditure by urban worker households [14; 19, p. 305]

	Percent
Blue collar workers	
Around 1897	32
1919	27
1926–27	16
1931–33	11
1936–38	15
White collar workers	
1920	18
1926–27	11
1931–33	8
1936–38	11
All urban workers	
1953	12.9
1954	12.7
1955	12.4
1956	11.9
1957	11.8
1958	11.1
1959	10.3
1960	9.5
1961	8.2
1962	7.0
1963	7.4
1964	6.6
1965	6.6
1966	6.0
1967	5.9
1968	5.6
1969	4.3

[4] This deflation was named after Finance Minister Matsukata who executed the deflation policy by consolidating paper currencies to establish the silver standard.

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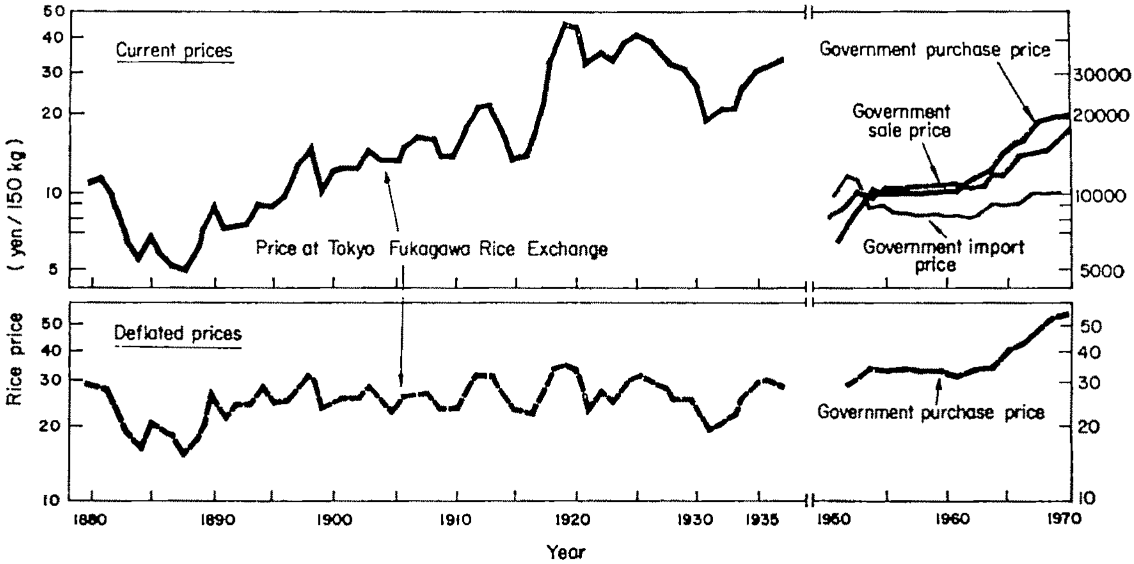

Figure 2. Changes in rice prices, both current and deflated by the general price index (1934–36 = 100), in Japan (log-scale in brown rice term), 1880–1937 and 1951–1970
Sources: Kayo [15, p. 514], JMAF [10] and Ohkawa [22; Vol. 8, p. 134]

in rice prices on such scale as to divert domestic prices several times above international prices.

Rice Policy for Industrial Development

Institutions for delivering marketable surplus

The policy which contributed most to increasing the marketable surplus of rice in the early Meiji period was the Land Tax Revision (1873–76).[5] To secure stable government revenue, the revision changed the feudal tax in kind levied in proportion to quantities harvested into a modern land tax in cash based on the fixed value of land. With this revision farmers and landlords were forced to market nearly one-quarter of the rice produced to pay the new land tax.

The Land Tax Revision had another important consequence: it concentrated property titles in the hands of landlords. Because the new land tax was fixed in cash, small farmers were often unable to pay the tax in years of bad harvest or low rice prices. They were compelled to borrow money from wealthier farmers or landlords, and many of them lost their land through foreclosure. This process accelerated during the Matsukata Deflation in the mid-1880's which resulted in a drastic decline in rice prices (Fig. 2). The area owned by landlords was less than 30 percent of the total arable land at the time of the survey for the Land Tax Revision. It rose to 40 percent in 1892 and had risen to nearly 50 percent by 1930 [23, p. 67].

In those days rent for paddy fields was paid in kind, roughly 50 percent of harvest, and the landlords, who had a much lower marginal propensity to consume rice, received the increase in the share of rice output. This in turn contributed to the increase in the surplus of marketable rice. Rice export in the early Meiji period was supported by the squeeze on farmers' incomes by heavy land tax and rent.[6]

A more "positive" measure to increase rice supply was to increase the productivity and output of rice. Shortly after the Meiji Restoration, the Japanese government tried to develop agriculture by importing western farm machinery and produce crops and livestock by western (Anglo-American) farming techniques. This policy of direct "technology borrowing" proved unsuccessful because of differences in climatic and economic conditions. During the

[5] The tax revision on arable land was largely completed by 1873, but was not completed before 1881 on forest and wild fields.

[6] According to Max Fesca, a German soil scientist employed by the Meiji Government, "The people of the lower class ate mainly the mixture of rice and barley prepared in the ratio of 1 to 2, or a porridge of millet and rice or of millet and barley, and, as a side dish, ate dried strips of radishes or vegetables of the season: they took almost no fish, even dried ones" [21, p. 182].

1880's the government shifted to a strategy of agricultural development which emphasized raising yields of traditional food staples—above all, rice.[7]

To effectuate this strategy, a labor-intensive and land-saving technology was developed by tailoring Japan's indigenous techniques after modern agricultural sciences from Germany (soil science and agricultural chemistry of the Liebig tradition). Establishment of the Itinerant Instructor System (1885) and the Experiment Station for Staple Cereals (1886), which grew into a national system of agricultural experiment stations, was in line with this strategy. The government also encouraged farmer organization for agricultural improvements such as *Nodankai* (society for discussing farming matters) and *Shushi Kokankai* (society for exchanging seeds) as media for improving and propagating better techniques.

As the result of such efforts, rice production gradually increased, but it failed to match the increase in demand during that initial spurt of industrialization which occurred after the recovery of the Matsukata Deflation and up to the Sino-Japanese War (1894–95). Japan turned from a net exporter of rice into a secular net importer. This raised serious public concern about foreign exchange and national security. Government efforts to counteract the increase in rice import by encouraging the domestic production of rice included the establishment of the National Agricultural Experiment Stations (1896), the Law of State Subsidy for Prefectural Agricultural Experiment Stations (1899), and the Arable Land Replotment Law (1899).

Efforts were successful to develop technology to raise yield per hectare by combining indigenous techniques and modern science, and by the beginning of this century a rather unique technology had been established. *Meiji Noho* (Meiji Agricultural Methods) was primarily based on seed improvement and higher fertilizer application with extremely labor-intensive land preparation, weed and pest control, and water management. With the development and propagation of *Meiji Noho*, Japan increased domestic rice supplies and prevented the further decline in rice self-sufficiency during the first two decades of a century of extremely rapid industrialization and per capita income growth without raising the price of rice relative to the general price level.

From tariff protection to imperial self-sufficiency

Voices for tariff protection of rice in terms of foreign exchange and national security considerations began to be raised when Japan became a net importer of rice. But voices for securing cheap rice for cheap labor were equally strong. It was in the first year of the Russo-Japanese War (1904–05) that the 15 percent ad valorem tariff was first imposed on imported rice.

This tariff was levied to increase the government revenue for financing the war,[8] and it was to be terminated at the war's end. Yet the landed interests lobbied to preserve this tariff, and succeeded in making it permanent in 1906 in the form of a specific duty of 0.64 *yen* per 60 kilograms.

Subsequently, the rice tariff became a major issue of public controversy, similar to those over the British Corn Laws and the German grain tariffs.[9] Like Malthus and Ricardo on the Corn Laws and Wagner and Brentano on the German grain tariff, Jikei Yokoi in the University of Tokyo and Tokuzo Fukuda in the Tokyo College of Commerce (Hitotsubashi University) represented the two camps. Yokoi, the foremost leader of agricultural fundamentalism, argued for the tariff on the basis of national security, including the preservation of agriculture as the source of strong soldiers and considerations for the balance of payments and the balanced growth of agriculture and industry. Fukuda retaliated on the basis of the economic doctrine of the Manchester School which favored free trade and industrial growth. The controversy continued in the arena of the National Diet. The Imperial Agricultural Society representing the landed interests and the Tokyo Chamber of Commerce representing the manufacturers and traders of export goods lobbied fiercely for opposite ends.

In 1913 the rice tariff controversy in the Diet came to a conclusion with the specific duty of one *yen* per 60 kilograms, which could be lowered by 0.4 *yen* by government order. An im-

[7] See Chapter 7 of Hayami and Ruttan [4] and Ogura [21] for the policies for increasing productivity and output of rice. For more detailed information, see Nogyo Hattatsushi [20].

[8] This tariff was also intended to appease landlords who accepted the increase in land tax for financing the War.

[9] For vivid descriptions of the controversy, see Mochida [17].

portant qualification was that the import of rice from overseas territories, Taiwan and Korea, was made free of duty. This decision pointed to the possibility of solving two conflicting policy goals, (a) self-sufficiency of rice and (b) supply of cheap rice for urban workers, by expanding the source of rice supply from Japan to its overseas colonies. This policy of imperial self-sufficiency was not deliberately adopted before *Kome Sodo* (Rice Riot) in 1920.[10]

Increase in rice yield and production, which had kept rice imports from rising, began to slow down in the mid-1910's. Technological potential in *Meiji Noho* was being exhausted as it was being perfected and propagated.[11] The agricultural experiment stations in their early days contributed to agricultural productivity growth by exploiting indigenous potential rather than by supplying new potential. The national experiment station gradually moved to conduct more basic research, including original crop breeding projects at the Kinai Branch by crossbreeding (1904) and at the Rikuu Branch by pure line selection (1905). Results of major practical significance lagged, however, for more than two decades.[12]

The exploitation of indigenous potential and the lack of new potential in scientific research, when confronted with the expansion of demand due to World War I, resulted in a serious rice shortage and a high price for rice. These naturally caused disruptions in the urban areas and culminated in the Rice Riot of 1918, which swept over the major cities in Japan.

Faced with a choice between high rice prices, high cost of living, and high wages on the one hand, and a drain on foreign exchange by large-scale rice imports on the other, Japan organized the imperial self-sufficiency programs. Under the program titled *Sanmai Zoshoku Keikaku* (Rice Production Development Program), the Japanese government invested in irrigation and water control and in research and extension to develop and diffuse high-yielding Japanese rice varieties adaptable to the ecologies of Korea and Taiwan.[13] Success of this effort created a tremendous rice surplus which flooded the Japanese market. Within 20 years, from 1915 to 1935, net imports of rice from Korea to Japan rose from 170 to 1,212 thousand metric tons per year, and net imports from Taiwan rose from 113 to 705 thousand metric tons. Because of this inflow of colonial rice, the net import of rice rose from 5 to 20 percent of domestic production.

Rice control to counteract colonial rice and depression

Success of the government program to develop Korea and Taiwan as major suppliers of rice to Japan was a mixed blessing. Such large-scale imports of rice, characterized by a relatively inelastic demand schedule, as expected lowered the price and discouraged the production of rice in Japan. A deterioration in the price and in the terms of trade for rice during this period was a logical consequence of the policies designed to increase imports from Korea and Taiwan.[14]

During the 1920's competition from colonial rice producers, together with the deflationary policy of the government to return to the gold standard at prewar parity, depressed agricultural prices and income. Finally, the World Depression hit Japan, resulting in a serious agricultural crisis, and the government was compelled to rescue this situation by supporting rice prices.

Attempts to stabilize rice prices by government purchase, sale, and storage activities had been discussed in 1913. In 1915 the Rice Price Adjustment Order was proclaimed, but little operation was done before 1920. When the price of rice began to fall in the 1920's, the Imperial Agricultural Society pressed the government to adopt a rice control program, the so-called "Ever-Normal Granary Plan." This brought about the Rice Law in 1921, which empowered the government to adjust rice supply in the market by (a) operating the purchase, sale, storage, and processing of rice within the financial limit of 2 thousand million *yen*, and (*b*) reducing or increasing the import duty and restricting imports from foreign countries.

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[10] According to Tobata before the Rice Riot, "... development efforts in Taiwan were concentrated on sugar production and little was done in Korea. It was claimed that the development of rice production in those overseas territories should be suppressed since it was to foster the competition against Japanese agriculture. ..." [20, p. 597].

[11] See Hayami and Yamada [5].

[12] See Nogyo Hattatsushi [20] or Ogura [21].

[13] For this process, see Hayami [2].

[14] For a detailed quantitative analysis, see Hayami and Ruttan [3].

In response to the rapid decline in rice prices in the late 1920's and 1930's, the Rice Law was amended in 1925, 1931, and 1932, raising the financial limit finally to 4.8 thousand million *yen*. In 1933 when a bumper crop caused a phenomenal surplus of rice, the Rice Law was replaced by the Rice Control Law which authorized the government to buy and sell unlimited quantities of rice at the floor and ceiling prices. The government rice control operation was extended to colonial rice.

Government storage reached a peak of 1.4 million tons at the end of 1934. After this year the balance of rice demand and supply took a dramatic turn. Increasing military involvement in China created effective aggregate demand, which expanded the demand for rice. Also, both labor and capital were diverted from productive purposes to military purposes. After the China Incident in 1937, shortages of labor and material inputs such as fertilizer were keenly felt. Government stores of rice rapidly decreased and were exhausted in 1939 by the severe drought which hit western Japan and Korea.

In the progress of the war the government was forced to take direct control of rice distribution and began with the Rice Distribution Control Act in 1939.[15] Increasing numbers of food items were added to the list of direct control and rationing. Finally, the Food Control Act, proclaimed the second year of the Pacific War in 1942, put nearly all items of food under the strict control of the government.

Rice Policy in the Post-War Growth

During the 20 years of "miraculous" recovery and growth of the Japanese economy after the devastation of World War II, rice shifted from a major wage good critical for industrial development to a minor item in household consumption expenditures. This change fostered a condition in which rice prices rose to an unprecedented level under the strong pressure of farmers requesting income and wage parity with urban workers. This section reviews this process and appraises rice policy relative to long-term historical trends.

[15] The most comprehensive review of rice policy and the food control program during and after the war may be seen in the Ministry of Agricultural and Forestry, Board of Food [9]. For a concise summary see Mochida [18] and Ogura [21].

Rice policy for economic recovery

The rice problem became an especially critical issue in Japan during the recovery from war devastation. A compulsory delivery of rice from producers at a price far below market equilibrium had to be enforced to maintain the subsistence of a majority of the urban population suffering acute food shortage and hyperinflation. Consumer price for the government ration of rice was set even lower than producer and import prices.

In 1946, by the direction of the General Headquarters of U.S. occupation forces, the government introduced the parity price formula for the determination of the producer price of rice. Theoretically, this formula guaranteed the same terms of trade of rice with the commodities that farmers had bought in the base years (1934–36). However, the commodity prices taken in the calculation of the parity index were the official prices of government rationing. Since farmers had to rely on black markets to a large extent for the purchase of both production and consumption goods, the parity price did not really guarantee "parity." To secure the delivery of rice at below-equilibrium prices, the Food Emergency Measure Act was promulgated in 1946, empowering the government to expropriate undelivered rice. Several incentive schemes were also designed, giving bonuses to producers who completed delivery.

The government also made substantial investments in reclamation, irrigation, drainage, agricultural research, and extension. Increase in food production was considered a necessary condition in the design for industrial recovery. In the program for the rehabilitation of industry, called *Keisha Seisanforshiki* (Differential Production Scheme), the government fund was first allocated to coal mining. Increased outputs of coal were delivered to fertilizer, iron, and steel industries; increased outputs in food from fertilizers and in iron and steel were returned to coal mining to expand the cycle of reproduction.

As industry was rehabilitated on the basis of compulsory delivery of cheap food, agricultural production recovered with the increased supply of industrial inputs to agriculture. Government controls on food commodities were lifted one by one: potatoes in 1949, wheat in 1952, etc. It was planned to lift the direct control on rice in

April 1952, but this plan was withdrawn because of the dark prospect of food supply during the Korean War.

The Korean War was a windfall to Japanese industry. Increase in military and civil procurement from the U.S. stimulated investment by raising capital returns and improved the balance of payments, providing the basis for a spurt of industrialization. Industrial production recovered to the prewar level by 1953 and continued to rise rapidly.

Disparity in income and wages between agriculture and industry increased after the Korean War boom. To cope with this situation, the determination of rice prices by the parity index was modified in 1952 to account for (1) lag in the level of consumption and living of rural households compared to urban households and (2) changes in the levels of material inputs to rice production. It was later decided that the government should consult not only the parity index but also the cost of rice production in determining the producer price of rice.

Despite these changes in the price determination formula, the price of rice was remarkably stable before 1960 (Fig. 2) and the deficit of the Food Control Special Account did not rise (Table 1). During the 1950's exporting from Japan was still dominated by the products of labor-intensive light industries such as textiles and toys. The balance of payments was the ceiling of the rate of industrial expansion and economic growth. In such situations it appears the rice policy was successful during the 1950's in contributing to industrial development by keeping the price of a critical wage good from rising, without causing a drain on foreign exchange and undue pressure on the national budget.

This success was based on (1) increases in rice productivity and output, especially after the bumper crop in 1955, resulting from public investments in land infrastructure and in agricultural research and extension; and (2) stability in the prices of industrial products purchased by farm producers. However, it does not seem likely that rice price stability could be maintained despite the strong political pressure of rice producers if the industrial development were not a national goal and rice were not a critical wage good for the development.

Changing role of rice and rice policy

The first big spurt of industrial development since 1955 ushered the Japanese economy into a new era. Within 10 years per capita income nearly trebled and approached the level of Western Europe. Both the industrial structure and the export structure came to be dominated by capital-intensive industries. Labor shortage became a secular feature of the economy after 1960, and the wage differentials were greatly reduced among different sizes of enterprises and between blue collar and white collar workers.

With the dramatic increase in income and wages of industrial workers, particularly low-income manual workers, their diet rapidly changed. Before 1960, decline in the starchy food staples in the total caloric intake of the Japanese was mainly attributed to the decline of inferior grains such as barley. From 1960 the share of rice also began to decrease (Fig. 1). The absolute per capita consumption of rice began to decrease sharply in 1965 (140 kilograms in 1955 to 117 kilograms in 1969). Rice in the consumption expenditures of urban worker households declined rapidly from 10.3 percent in 1959 to 4.3 percent in 1969 (Table 2). Importance of rice as a determinant in the cost of living of urban workers was drastically reduced. Rice was no longer the critical wage good for industrial development.

By 1960 disparities between agriculture and non-agriculture in net product (or income) per worker and income per capita of population were wide open (see Column G, Table 3 and Column B/D, Table 4). It was natural that farmers tended to identify the declining price of rice as the cause of growing income disparity. Strong demands from farmers for fair returns for their labor resulted in 1960 in a rice price determination formula called the "Production Cost and Income Compensation Formula."

In this formula the price of rice is determined by the cost of production at the paddy field in which yield per hectare is lower than the national average by one sigma (one standard deviation). Since rice yield per hectare is in general inversely correlated with the cost of production per unit of output, this formula implies that the price thus determined covers the cost of production of marginal producers ("marginal" in the sense of a cost lower than average by about one standard deviation). A critical point in this formula is that wages for family labor are valued by non-farm wages in order to guarantee "fair returns" for the labor of rice producers.

With this formula the producer price of rice rose rapidly, corresponding to the rise in indus-

Table 3. Changes in relative productivity and relative prices between agriculture and manufacturing, 1953–68 [7, 13]

Year	Net product per worker[a] (current prices) Agriculture A	Manufacturing B	Ratio of net product per worker (current prices) $C=A/B$	Index of product prices Agriculture[b] D	Manufacturing[c] E	Relative price index $F=D/E$	Ratio of net product per worker (constant prices) $G=C/F$
	1000 *yen*		percent	1960=100			percent
1953–55 av.	68	225	30	101	102	99	30
1960	98	445	22	100	100	100	22
61	111	500	22	109	100	109	20
62	122	514	24	120	98	122	20
63	130	616	21	128	99	129	16
64	146	646	23	134	99	135	17
65	167	682	24	149	99	151	16
66	191	777	25	160	101	158	16
67	245	910	27	174	102	171	16
68	290	1017	29	177	102	174	17

[a] Net domestic product at factor cost per gainful worker. Agriculture workers include forestry workers. 1968 data are preliminary.
[b] Ministry of Agriculture and Forestry index of agricultural product prices at farm gate.
[c] Bank of Japan index of wholesale prices of manufacturing products.

trial wages. It doubled from 10.4 thousand *yen* per 150 kilograms of brown rice[16] (193 U.S. dollars per metric ton) in 1960 to 20.6 thousand *yen* (382 U.S. dollars) in 1968. The difference between producer price and import price increased from less than 20 percent to more than 100 percent. As shown in Figure 2, the domestic price of rice as deflated by the general price index deviated during the 1960's from a stable boundary held over from the Meiji period through 1960.

[16] Brown rice is husked but unpolished rice. Conversion factors both from paddy to brown rice and from brown rice to polished rice are roughly 80 percent.

The Production Cost and Income Compensation Formula was designed to reduce the gap between farm and non-farm income and wages. This policy goal seems to have been satisfied with the rising prices. Income per agricultural worker compared to the income of manufacturing workers improved from 1960 to 1968 with the rapid rise in agricultural prices relative to manufacturing prices. This more than compensated for the relative decline in the net product per farm worker in real terms (Table 3). Increase in the price of rice, which constituted about 40 percent of the total value of agricultural output, was a major factor in im-

Table 4. Changes in relative income between farm and urban worker households, 1953–1968 [13, 14]

Year	Farm household: Income per household: Farm income	Off-farm income[a]	Total A	Total income per person B	Urban worker household income[a] per household C	person D	Relative income per household A/C	person B/D
	1000 *yen*						percent	
1953–55 av.	211	139	350	55	334	70	105	79
1960	239	210	449	78	491	112	91	70
1961	258	243	501	89	542	128	92	70
1962	294	287	571	103	610	146	94	71
1963	317	325	642	118	655	157	98	75
1964	350	382	732	136	732	176	100	77
1965	401	434	835	157	797	194	105	81
1966	455	493	948	182	870	215	109	85
1967	562	573	1135	221	967	240	117	92
1968	579	669	1248	247	1068	272	117	91

[a] Includes transfer income.

Table 5. Net returns to labor (per hour)[a] by major farm products, 1965–67 averages [8b, p. 22]

	Yen/hour	Rice = 100
Rice	306	100
Wheat	91	30
Potatoes	225	73
Sweet potatoes	140	46
Red beans	167	55
Cucumber	167	55
Tomato	181	59
Tangerine orange	346	113
Apple	117	58
Rapeseeds	119	39
Tobacco	118	38
Tea	226	74
Cocoon	153	50
Milk	145	47
Egg	182	59
Hog	137	45

[a] The value of output minus the cost of production (except labor wages) divided by the hours of labor. The production cost includes land rent, capital interest and depreciation, and current input expense.

proving relative income for agriculture. Rise in agricultural prices, together with increase in off-farm income, resulted in a marked reduction in the gap in income per person and per household between agriculture and non-agriculture (Table 4).

Satisfaction of the income parity objective involved substantial loss of economic efficiency. High rice prices should have reduced consumer surplus not only by contracting the demand for rice itself but also by obstructing the shift of resources from rice to other high-demand agricultural products such as livestock and vegetables. The support of rice prices also depressed the out-migration of agricultural labor to non-agriculture.

More conspicuous squanders were the rapidly accumulating surplus rice in government storage and the multiplying deficit from the food control program. Already in 1965–67 had the production of rice become so much more profitable than other agricultural products (Table 5) that resources had been shifted to rice production. Rice production continued to rise until it reached a record 14.4 million tons in 1967. Meanwhile, consumption remained stable until 1965, when it rapidly declined, resulting in the annual addition of 2 million tons to the government rice storage. The deficit from the rice control program reached 40 percent of the budget of the central government for agriculture and forestry, nearly 5 percent of the total 1968 national budget.

How could such squander of resources and loss of economic efficiency be tolerated during the 1960's? Certainly, it was the extremely strong political pressure of farm organizations which achieved the handsome rise in rice prices. Although the farm population declined in the course of rapid industrial growth, electoral districts have changed little, leaving the political weight of farm votes intact.[17] Rural districts have continued as solid conservative blocks, which the present government could not dare to lose.

Why then were the powerful rural votes unsuccessful in raising the price of rice during 1950's? Why couldn't the equally strong (or stronger) political power of landlords before the War achieve a comparable support on rice? It appears that this question can be answered only in terms of decline in the role of rice as a wage good for industrial development. As has been observed, importance of rice as a determinant of the cost of living of industrial workers was greatly reduced during the 1960's. Because of the rise in capital intensity and the transformation in industrial structure, increases in the cost of living and in wages became less critical for the international competitive power of Japanese industry. Rice was no longer a critical wage good for industrial development. This appears to be the reason why the government and society yielded to the pressure of farmers for increases in rice prices.

In retrospect, the cost of rice support in the past decade was a cost of economic growth that society had to bear; to some extent, like inflation or environmental pollution, it had a trade-off with economic growth. If the price determination had been left to market mechanism, there never would have been a dramatic decline in rice prices to result in an extremely wide income disparity between the rural and urban sectors. Eventually, labor and other agricultural resources would have been efficiently reallocated to the production of other agricultural commodities or to manufacturing and service industries. But this might have generated more social tension than the present political system could have absorbed.

Prospect

By the end of the 1960's it had become apparent the cost of rice support exceeded the

[17] There is an estimate that one vote in rural districts is worth 4 to 7 votes in Tokyo. See Henmi [6, p. 200].

Table 1. Basic project data, selected Peruvian irrigation projects (1965 prices) [3, 4, 6, 7, 11]

Irrigation projects by class	Hectares			Investment cost per hectare $[a]	Gross output hectare[b] $[a]	Income per hectare[b] $[a]	Time required (years)	
	New	Improved	Total				For construction	To reach full output
Small sierra		3,625	3,625	670	310	170		
1. Antaura		1,175	1,175	560	250	190	2	7
2. Huanscolla		925	925	610	400	190	2	5
3. Chococo		1,525	1,525	800	290	150	2	7
Small coastal	7,255		7,255	1,570	850	370		
1. El Cural	3,065		3,006	1,440	910	390	1	8
2. La Cano	2,120		2,120	1,730	760	350	1	8
3. El Huevo	2,070		2,070	1,600	850	360	1	8
Large coastal	86,751		86,751	2,780	820	470		
1. Olmos	86,751		86,751	2,780	820	470	19	20
Medium coastal	31,366	66,929	98,295	1,530	430	230		
1. Choclacocha	8,500	28,000	36,500	1,440	490	270	3	7
2. Chira	7,471	28,471	35,585	1,640	300	180	4	12
3. Moquequa	3,080	3,670	6,750	1,750	660	290	3	12
4. Tumbes	12,315	7,145	19,460	1,390	470	210	7	12
Total or average	125,372	70,554	195,926	2,060	620	340		

[a] The dollar amounts were obtained by converting the soles figures at the prevailing exchange rate of soles 26.80 = $1.
[b] Average annual at full capacity output.

vestment criteria, namely, the output-investment ratio, the labor-investment ratio and the foreign exchange earnings-investment ratio. Each criterion is computed from the present discounted values of the projects. In addition, approximations of the shadow prices of unskilled labor and foreign exchange are introduced.[3]

and Little and Mirrlees [9]. Estimates of the internal rate of return are not enumerated in later sections because the priorities obtained coincide closely with those of the BCR.

[3] Throughout the exposition the terms shadow wage rate and shadow foreign exchange rate are used. They are defined as the opportunity costs of employing additional quantities of each resource in the new investment projects. With respect to labor, Thorbecke and Stoutjesdijk [13] have shown that there is substantial underemployment of labor in the Peruvian agricultural sector. Thus, the prevailing market wage rates likely overestimate the output which is sacrificed by withdrawing labor from agriculture even during months of peak labor demand. No direct estimates of the shadow wage rate are available, but for project evaluation it is far better to account for an overvaluation of labor than not. The shadow exchange rate is defined as the equilibrium rate that would prevail without major exchange controls. Since the market rate used for the initial project evaluation was that which prevailed in 1965, the shadow rate adjustment employed merely reflects closely the approximate 40 percent devaluation of 1967. Furthermore, this new rate prevails under a regime of continued exchange controls.

The benefit-cost ratio (BCR) measures the ratio of the present discounted value of direct project benefits to the present discounted value of direct project costs. That is,

$$(1)\quad BCR = \sum_{t=0}^{N} B_t(1+i)^{-t} \Big/ \sum_{t=0}^{N} C_t(1+i)^{-t}, \qquad t = 0, 1, \cdots, N$$

where

$$(1.1)\quad B_t = X_t - C_{xt} - I_{at} - O_{at}, \qquad \text{and}$$

$$(1.2)\quad C_t = I_t + O_t.$$

The project benefits in time t, B_t, are composed of gross output, X_t, less operating costs, C_{xt}, on-farm investment costs, I_{at}, and the operating, maintenance, and replacement costs, O_{at}, of the on-farm investment. The project costs in year t, C_t, are the sum of public infrastructure investment, I_t, and their corresponding operating, maintenance, and replacement costs, O_t. Thus, the private farm investment (I_{at}) is included as a negative benefit, and public (infrastructure) investment (I_t) is treated as a positive cost. Furthermore, because of data

limitations, secondary and indirect benefits are ignored.[3]

The social marginal productivity of investment (SMP) as elaborated by Chenery [1] consists of two components: the social profitability ratio[4] and the balance of payments effects of project operation and investment. Therefore,

$$(2) \qquad SMP = \frac{V - C}{K} + r\,\frac{B}{K}$$

where V is the present value of the domestic value added composed of gross output less imported material costs and C is the present value of operating costs made up of labor and domestic material costs. The present value of project investment costs are denoted by K, while r is the proportion by which the shadow exchange rate exceeds the official rate, i.e., the extent of overvaluation of the exchange rate.[5] The term B is the present value of the total balance of payments effects computed to include the direct and indirect effects of the project investment (B_1), the direct operating effects (B_2), and the indirect operating effects (B_3). In functional terms,[6]

$$(3) \qquad B = B_1(K) + B_2(X) + B_3(X).$$

In addition to the above criteria, three partial ratios can be used in project selection, utilizing limited project information to measure the contribution of investment to specific development targets. These criteria are the output-investment ratio, the employment-investment ratio, and the foreign exchange earnings-investment ratio.

The output-investment ratio is defined as the present discounted value of a measure of output (gross output, value-added or income) divided by the present discounted value of investment. That is,

$$(4) \quad X/K = \sum_{t=0}^{N} X_t(1+i)^{-t} \Big/ \sum_{t=0}^{N} K_t(1+i)^{-t}, \qquad t = 0, 1, \cdots, N.$$

The employment-investment ratio is similarly measured as the present discounted value of unskilled labor costs per unit of the present discounted value of project investment. Hence,

$$(5) \quad L/K = \sum_{t=0}^{N} L_t(1+i)^{-t} \Big/ \sum_{t=0}^{N} K_t(i+i)^{-t}.$$

The net direct foreign exchange earnings per unit of project investment, expressed in present values, is given by the ratio

$$(6) \quad F/K = \sum_{t=0}^{N} F_t(1+i)^{-t} \Big/ \sum_{t=0}^{N} K_t(1+i)^{-t}.$$

Project Priorities

Each of the previously defined investment criteria is applied to the irrigation projects, permitting specification of independent priorities according to each criterion.

The BCR was computed for the set of projects using a 10 percent discount rate and two sets of prices corresponding, respectively, to market and selected shadow prices of labor and foreign exchange. The results (Table 2) are representative of the effects of shadow rate adjustments. Inclusion of these rates causes the BCR of each project to rise regardless of the discount rate chosen. The higher the discount rate, the more crucial the choice of shadow prices in determining the feasibility, i.e., $BCR \geq 1$, of projects. Thus, for example, among the projects being considered only two are feasible at market prices using a 15 percent discount rate, whereas eight would be feasible at the chosen shadow prices.

Failure to include shadow prices, common in Peruvian feasibility studies, understates benefit-cost ratios over the whole range of discount rates. Indeed, this omission can alter the composition of the final project selection by overestimating the contribution of capital intensive

[3] The benefits of the one large project (Olmos) were estimated in the feasibility study to account for projected reductions in product prices arising from the project's contribution to national output. The remaining studies implicitly assumed an infinitely elastic demand for each project's output.

[4] See Little and Mirrlees [9] for an analysis of the social profitability ratio from the viewpoint of the firm and society.

[5] As defined here, r corresponds to the ratio of the shadow exchange rate minus the official exchange rate to the latter, i.e., $r = (F-O/O)$ where F = shadow exchange rate expressed as number of soles per U.S. \$, and O = the official exchange rate, i.e., 26.8 soles = \$1 in 1967; thus, $r = (F/O) - 1$. $F/O = f$ and $r = f - 1$ can be expressed where f becomes the shadow exchange rate as a proportion of the official rate. Thus, for example, $f = 1.5$ implies a shadow rate of 50 percent above the official rate, i.e., 40.2 soles = \$1. (See footnote 9 for more detail.) In the sensitivity analysis which is conducted in a later part of this paper the shadow foreign exchange rate is expressed as f. In any case, r is always equal to $f - 1$ as shown above.

[6] The balance of payments effect is described in detail by Chenery [1] and in the U. N. project manual [14].

Table 2. Project values for the benefit-cost ratio (BCR) and the social marginal productivity of investment (SMP) [3, 4, 6, 7, 11][a]

Project	BCR at market prices	BCR at accounting prices[b]	Project	SMP[b]	$(V-C)/K$	$0.5(B/K)$
Huanscolla	2.4	4.7	Huanscolla	3.6	2.8	0.83
Antaura	2.4	3.7	Antaura	2.8	2.4	0.38
Choclacocha	1.5	3.2	El Cural	1.7	1.5	0.21
Chococo	1.5	2.7	El Huevo	1.7	1.5	0.19
Olmos	1.4	2.1	La Cano	1.5	1.2	0.26
El Cural	1.4	2.2	Chococo	1.4	1.2	0.23
La Cano	1.4	2.2	Choclacocha	1.3	1.3	0.01
El Huevo	1.4	2.5	Olmos	1.1	0.8	0.26
Moquequa	1.0	1.4	Tumbes	0.5	0.4	0.08
Tumbes	0.8	1.5	Moquequa	0.3	0.4	0.15
Chira	0.5	0.6	Chira	−0.6	−0.3	−0.27

[a] Discounted at a 10 percent rate of interest.
[b] Computed at a foreign exchange rate of 150 percent of the official rate and a wage rate of 50 percent of the market rate.

projects requiring large initial foreign exchange outlays and relatively fewer unskilled workers during the construction phase.[7]

The SMP is a useful adjunct to benefit-cost analysis because the balance of payments effects are separated from the total effects of the project investment and operation. The magnitude of the SMP and its two components are given in Table 2 for the set of projects, assuming as before a shadow foreign exchange rate of 150 percent of the official rate and a shadow wage rate of 50 percent of the market rate.

Incorporation of the indirect balance of payments effects in the SMP is responsible for a substantial change in the ranking of the projects as compared to that resulting on the basis of the BCR criterion. More specifically, the large projects (Choclacocha and Olmos) which have a substantial foreign exchange component have a relatively lower ranking on the basis of the SMP than the BCR criterion. This demonstrates the limitations of relying on a single direct measure of project performance, even for a set of relatively homogeneous projects.

Three categories of partial criteria are computed in Table 3. First, one measure of the output-investment ratio is shown.[8] The variation

[7] The project employment effects are quantified in Table 3.

[8] Many other forms of the output-investment ratio were computed including the use of value added and investment

Table 3. Output-investment, labor-investment, and foreign exchange-investment ratios [3, 4, 6, 7, 11][a]

Gross output-investment ratio: Project	X/K	Labor-investment ratios: Project	Total $(L_o+L_c)/K$	Operation phase L_o/K	Construction phase L_c/K	Foreign exchange-investment ratio: Project	F/K
Huanscolla	5.4	Huanscolla	0.89	0.66	0.23	Huanscolla	2.7
Antaura	3.7	El Cural	0.79	0.60	0.19	Antaura	1.6
El Cural	3.6	El Huevo	0.76	0.51	0.25	Olmos	1.3
El Huevo	3.6	Choclacocha	0.63	0.43	0.20	Chococo	1.2
Choclacocha	3.6	La Cano	0.58	0.39	0.19	La Cano	1.2
La Cano	3.3	Chococo	0.57	0.33	0.24	El Cural	1.1
Chococo	3.2	Olmos	0.52	0.36	0.16	El Huevo	1.0
Olmos	2.8	Tumbes	0.52	0.36	0.16	Tumbes	0.6
Moquequa	2.5	Moquequa	0.47	0.34	0.13	Choclacocha	0.5
Tumbes	2.2	Antaura	0.46	0.24	0.23	Moquequa	0.4
Chira	1.5	Chira	0.27	0.16	0.11	Chira	−0.1

Source: Same as Table 1.
[a] All ratios were computed on the basis of a 10 percent annual discount rate.

in priorities between it and the BCR are not great but the use of gross output overestimates benefits and, therefore, is not appropriate for determining feasibility. Thus, it should be used only for project comparison when no other measures are available.

Second, the employment-investment ratio is broken down over two project employment periods, namely, the construction and operating phases. It can be seen that employment effects during the operation phase are significantly larger than during the construction phase. It is evident that small projects require more labor per dollar of investment in the operating and construction phases.

The final partial investment criterion which is computed in Table 3 is the ratio measuring the direct foreign exchange contribution of each project. There is a striking uniformity in project rankings between this ratio and the balance of payments component of the SMP given in Table 2.

Sensitivity Analysis

Shadow prices of resources, e.g., capital, foreign exchange, and unskilled labor, can be estimated only within the context of an economy-wide, sectoral, or microeconomic model. For planning purposes such estimates should be derived from an economy-wide multisectoral model. In the absence of such a model and corresponding estimates, an alternative procedure is to conduct a sensitivity analysis of the investment criteria to systematic variations in the prices of the principal limiting resources over a realistic range. The BCR is subjected to this sensitivity analysis over the following range of shadow prices for foreign exchange: between the official rate and twice that rate; for the wage rate: between zero and the market rate; and for the interest (discount) rate: between 6 and 15 percent per annum. Thus,

$$BCR = g(f, w, i), \quad \text{for} \quad 1.0 \leq f \leq 2.0, \quad 0 \leq w \leq 1.0, \quad \text{and} \quad 0.06 \leq i \leq 0.15 \tag{7}$$

where:

f = the shadow foreign exchange rate as a proportion of the official rate,[9]

w = the shadow wage as a proportion of the market wage, and

i = the interest (discount) rate.

The sensitivity of the BCR to parametric variations in the foreign exchange, wage, and interest rates is illustrated in Figure 1. It can be seen that the BCR is highly sensitive to changes in the interest rate, holding f and w constant; an increase in i reduces the BCR uniformly for all projects. Similarly, a reduction in the price of unskilled labor (w) increases all BCR's as does a

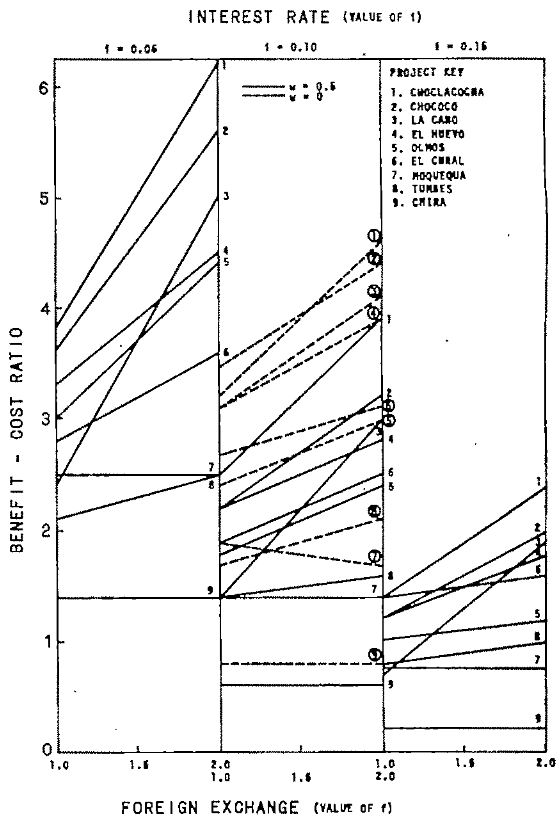

Figure 1. Sensitivity of the Benefit-Cost Ratio (BCR) to variations in foreign exchange, wage and discount rates. (See text)[a]

[a] Two projects (Antaura and Huanscolla) are not shown here because their relative ranking is invariant over the whole range of chosen shadow prices and discount rates. These two projects would occupy the first two ranks for any values of the shadow prices and discount rates selected here if they had been included in the sample.

Source: Computed on the basis of data in [3, 4, 6, 7, 11].

with and without operating and maintenance costs, but the variation in priorities was sufficiently small to exclude them from Table 3.

[9] Expressed in soles per dollar. Thus, since the official (market) exchange rate was equal to 26.8 soles = $1 in 1965; $f = 1.0$ means the market rate; $f = 1.5$ implies a shadow rate of 40.2 soles = $1; and $f = 2.0$ implies a shadow rate of 53.6 soles = $1. The sol was devalued in 1967 and the present (1970) rate of exchange is 38.7 soles = $1.

change in the foreign exchange rate (f is increased).

Although changes in i, f, and w affect the absolute values of the BCR's substantially, the priorities are not greatly altered. For example, a reduction in unskilled labor costs from 50 percent of market costs to a price of zero (with $i=0.10$) increases the BCR's, but the priorities do not change over the selected exchange rate range.

The sensitivity analysis reveals an important result in the evaluation of Peruvian irrigation projects. By reducing the wage to at least 50 percent of the market price and by increasing the domestic currency cost of foreign exchange to at least 150 percent of the official rate, the choice of the interest rate between 6 and 15 percent has little effect on the project ranking. Thus, the use of shadow wage and exchange rates, especially with the range employed, effectively eliminates for Peruvian irrigation planners the difficult task of selecting an appropriate interest rate for discounting purposes.

An Irrigation Investment Program Related to Macroeconomic Objectives

The Peruvian National Planning Institute [5] specified without inferring priorities four major national objectives: (1) increased per capita income, (2) reduced dependence on international markets, i.e., balance of payments equilibrium, (3) reduced underemployment and unemployment, and (4) a more equitable distribution of income.

The process of project selection designed here involved the selection of appropriate investment criteria measuring the contribution of each project to the distinct national targets above. With respect to the income objective, two criteria are available—the BCR and the social marginal productivity of investment, SMP. The main difference between the BCR and the SMP is that the latter includes the indirect effects on the balance of payments. A final judgment as to whether the BCR or the SMP should be used to reflect the income objective would depend on the indirect balance of payments effect and any other secondary effect that might have been included in one criterion or the other.

The effect on the balance of payments of the project investment and operation is measured by the last component of the SMP (B/K) or the foreign exchange-investment ratio (F/K).

The goal of increased employment is represented by the employment-investment ratio. The income redistributional objective is not explicitly treated; nevertheless, the employment criterion might be used as an indirect measure of the increased income of unskilled low income workers in different functional groups and regions stemming from an investment program.[10]

Priorities among projects can be determined on the basis of each project's contributions to the aforementioned objectives. Two such ranking schemes are proposed here, one ordinal and the second cardinal.

In the ordinal ranking scheme, each project is ranked according to the value of the appropriate investment criterion reflecting each corresponding macroeconomic objective. Thus, for the current demonstration a mean ordinal ranking of the set of projects is obtained between the SMP and the BCR criteria and is then treated as the final ordinal ranking reflecting the income objective[11] (column 1, Table 4). Likewise, since there are only minor differences in the ordinal ranking obtained on the basis of the foreign exchange-investment ratio (F/K), given in the last column of Table 3, and the balance of payments component of the SMP (B/K), which can be inferred from Table 2, the mean ordinal ranking on the basis of these two criteria was computed and used to reflect the balance of payments objective (column 3, Table 4). The employment-investment ratio was used to reflect the goal of increased employment and a more equal income distribution (for the ordinal ranking corresponding to the employment objective, see column 6, Table 4).

A second alternative ranking method is formulated to reflect more clearly the cardinal differences of projects according to the investment criteria. Instead of ranking projects ordinally for each criterion, the ratio of the value of each project's performance for any

[10] Marglin [10] and Little and Mirrlees [9] infer that the goal of redistributing income can be indirectly represented by the employment effect of project investment and operation. For a recent study in which there is presented a framework to define and measure the redistributional effects among income classes of the single efficiency (output) objective, see Kalter and Stevens [8].

[11] For the irrigation projects, the mean ranking of the BCR and the SMP does not significantly affect the final ranking, but this result is unlikely for a more heterogeneous group of projects, e.g., a coastal irrigation project versus a jungle colonization project. Indeed, the final choice between the BCR and the SMP would depend upon the project analyst's judgment regarding the accuracy of the indirect balance of payments effects of the SMP and the possibility of including the indirect effects in the BCR.

Table 4. Ordinal project rankings by econonic objectives and cardinal measures of projects' contributions to economic objectives*

Income objective (Y)			Balance of payments objective (B)			Employment objective (E)		
Project	Ranking		Project	Ranking		Project	Ranking	
	Ordinal Y^p	Cardinal $\bar{Y}^p$		Ordinal B^p	Cardinal $\bar{B}^p$		Ordinal E^p	Cardinal $\bar{E}^p$
Huanscolla	1	2.26	Huanscolla	1	3.50	Huanscolla	1	1.52
Antaura	2	1.77	Antaura	2	1.77	El Cural	2	1.35
El Huevo	3	1.12	Olmos	3	1.33	El Huevo	3	1.29
Choclacocha	4	1.13	La Cano	4	1.25	Choclacocha	4	1.07
El Cural	5	1,06	Chococo	5	1.19	La Cano	5	0.99
Chococo	5	1.06	El Cural	6	1.08	Chococo	6	0.97
La Cano	7	0.99	El Huevo	7	0.98	Olmos	7.5	0.89
Olmos	8	0.83	Tumbes	8	0.53	Tumbes	7.5	0.89
Tumbes	9	0.49	Choclacocha	9	0.28	Moquequa	9	0.80
Moquequa	10	0.40	Moquequa	10	−0.08	Antaura	10	0.78
Chira	11	−0.09	Chira	11	−0.78	Chira	11	0.46

* Source: Based on Tables 2 and 3. For explanation of methodology used to compute ordinal and cardinal values see text.

given investment criterion to the mean value of all projects for the same criterion was computed. The advantage of using the latter measure as a decision rule in the project selection process is that, in contrast to the ordinal method, it avoids discriminating against projects which are clearly superior in terms of the magnitude of given investment criteria but only slightly inferior in terms of other criteria.[12]

Thus, for project p, the cardinal magnitude for each criterion is determined

$$\overline{BCR^p} = \frac{BCR^p}{\sum_{p=1}^{n} \frac{BCR^p}{n}} \tag{8}$$

where $p=1, 2, \ldots, n$ projects (in the specific example $n=11$); and BCR^p is the value of the BCR for project p and,

$$\overline{SMP^p} = \frac{SMP^p}{\sum_{p=1}^{n} \frac{SMP^p}{n}} \tag{9}$$

and similarly for the remaining criteria $(\overline{B/K})$, $(\overline{F/K})$, and $(\overline{L/K})$.

[12] For example, assume (1) two projects, A and B; (2) two investment criteria (reflecting two macroeconomic objectives) α and β, which are equally weighted. If project A has a magnitude of α which is twice as large as that of project B, while B's performance according to criterion β is only 1 percent higher than that of A, an ordinal comparison of these two projects would fail to distinguish between them since their mean ranking would be the same. On the other hand, a decision rule based on cardinal values of the investment criteria would clearly select A over B.

The cardinal measures of each project's relative contribution to the macroeconomic objectives are obtained in a similar way as in the case of the ordinal rankings by taking the arithmetic average between $\overline{BCR^p}$ and $\overline{SMP^p}$ to reflect the income objective and between $\overline{B/K}$ and $\overline{F/K}$ to reflect the balance of payments objective.

Table 4 gives the resulting ordinal project rankings according to the three economic objectives and the cardinal measures of each project's contributions to the latter.

Investment criteria (usually limited to the BCR in pre-investment studies) are typically unidimensional and partial in nature. They tend to be applied simply to individual projects in the process of selection. On the other hand, national developmental policy objectives are macroeconomic and multidimensional by their very nature. Hence, an attempt is made below to formulate a methodology permitting a quantitative evaluation and selection of projects, given the major policy objectives of the government. A national preference function including the major policy targets can be postulated. The authors have chosen to express the preference function as a linear function of the three major policy objectives mentioned above.[13] It is clear that the relative weights attached to these macroeconomic targets can change depending on the initial conditions and the preferences of the decision makers.

[13] A number of macroeconomic policy models have been constructed which specified preference functions. For an example of such a model, using a linear preference function, see Van Eijk and Sandee [15]; for a policy model using a quadratic preference function, see Theil [12].

$Y^p(\bar{Y}^p)$ are the ordinal ranks (cardinal measure) of each project according to the income objective, while $B^p(\bar{B}^p)$ and $E^p(\bar{E}^p)$ stand for the corresponding ordinal ranks (cardinal measures) of the projects in terms of the balance of payments and employment objectives. The ordinal range for each of the above variables is from 1 to 11 since there are 11 projects in the sample. The cardinal range depends upon the relative magnitudes of the criteria shown in Table 4. A weighted linear function of these objectives could then be used as a decision rule in the selection of projects according to their weighted contributions (ordinal and then cardinal) to the major national economic goals, as follows:

$$(10) \qquad R^p = yY^p + bB^p + eE^p$$

or for the cardinal rule

$$(10.1) \qquad \bar{R}^p = y\bar{Y}^p + b\bar{B}^p + e\bar{E}^p$$

$$\text{where } p = 1, 2, \cdots, 11$$

and y, b, and e stand for the relative weights attached to the corresponding objectives so that

$$(11) \qquad y + b + e = 1.$$

A final weighted ranking can be defined for each set of weights, with index j as

$$(11.1) \qquad R_j = R_j(y, b, e)$$

or

$$(11.2) \qquad \bar{R}_j = \bar{R}_j(y, b, e) \qquad j = 1, 2, 3, 4.$$

Four sets of weights are considered (Table 5). In the ranking alternative R_1, each goal receives an equal weighting in the policy maker's preference function, and for the remaining alternatives (R_2, R_3, and R_4) each objective in turn is weighted twice as heavily as the remaining objectives. It is, of course, clear that a parametric test of the sensitivity of the final ranking (R_j) to variations in the welfare weights i.e., in j, can be undertaken.

Table 5. Alternative preference weights

R_j (or $\bar{R}_j$)	y	b	e	$y+b+e=1$
R_1	0.33	0.33	0.33	1.00
R_2	0.50	0.25	0.25	1.00
R_3	0.25	0.50	0.25	1.00
R_4	0.25	0.25	0.50	1.00

Table 6 provides the resulting project ordering under the four weighting schemes specified previously to test the sensitivity of these rankings to changes in welfare weights. It can be seen that the irrigation project priorities derived by the four weighting schemes are remarkably similar. The smaller sierra and coastal projects are ranked consistently high and, with the exception of Choclacocha, the medium-sized projects do not perform well. The small projects perform uniformly well given the major national objectives irrespective of the choice of weights. The one large project (Olmos) maintains a uniform ranking as well. Hence, in this case Peruvian policy makers can look to small sierra and coastal projects to satisfy best the prevailing objectives over a wide range of different welfare weights.

A comparison of the rankings in Table 6 shows that they are only very marginally affected by applying the cardinal rather than the ordinal decision rule to the present set of projects. However, important additional information is provided regarding the relative quantitative extent to which any given project compares with others under various alternative

Table 6. Relative project priorities according to four alternative weighting schemes of macroeconomic objectives, cardinal and ordinal methods[a]

R_1	$\bar{R}_1$	R_2	$\bar{R}_2$	R_3	$\bar{R}_3$	R_4	$\bar{R}_4$
Huanscolla	2.43	Huanscolla	2.39	Huanscolla	2.70	Huanscolla	2.20
El Huevo	1.13	El Huevo	1.13	Antaura	1.52	El Cural	1.21
El Cural	1.15	Antaura	1.52	El Cural	1.14	El Huevo	1.17
Antaura	1.44	El Cural	1.14	La Cano	1.12	La Cano	1.06
Chococo	1.07	Chococo	1.07	El Huevo	1.09	Choclacocha	0.89
La Cano	1.07	La Cano	1.06	Chococo	1.10	Chococo	1.05
Choclacocha	0.82	Choclacocha	0.90	Olmos	1.10	Antaura	1.28
Olmos	1.01	Olmos	0.97	Choclacocha	0.69	Olmos	0.99
Tumbes	0.62	Tumbes	0.59	Tumbes	0.60	Tumbes	0.69
Moquequa	0.37	Moquequa	0.38	Moquequa	0.26	Moquequa	0.48
Chira	−0.14	Chira	−0.13	Chira	−0.30	Chira	0.01

[a] Projects are listed by name in their ordinal ranking and in each case the numerical value gives the cardinal measure. Based on Table 4.

macroeconomic preference schemes. Thus, for example, the test reveals that Huanscolla is far superior in terms of its contribution to the macroeconomic objectives per unit of investment than any other project. In the same vein, it can be seen that five projects are very closely clustered in the third weighting alternatives ($\overline{R}_3$) between a weighted index of 1.09 (El Huevo) and 1.14 (El Cural). Given the marginal difference separating these projects, no clear-cut choice presents itself within this subset if the relevant weights are those of alternative R_3.

Summary and Conclusions

A method of selecting investment project priorities has been presented and applied to 11 Peruvian irrigation projects. Central to this analysis is a function that explicitly incorporates the national economic targets with appropriate weights. Initially, a specific investment criterion is paired with each development objective, be it income generation, employment creation, or balance of payments equilibrium. A ranking function which combines these various objectives is then defined and expressed in ordinal and cardinal terms. This ranking function appears to be a very general and applicable device which can be extended easily to incorporate as many goals as necessary or desired as long as the corresponding investment criteria can be specified and computed.

Each investment criterion yields a set of priorities. Approximations of the shadow prices of labor, capital, and foreign exchange are introduced and the sensitivity of the benefit-cost ratio to variations in these prices is undertaken. This analysis revealed that although the absolute magnitude of the benefit-cost ratios is sensitive to changes in the shadow prices, the priorities to a significant degree are invariant to changes in the rate of interest when combined with shadow wage and exchange rates—at least over a fairly wide range of the latter.

With respect to the specific irrigation project priorities, it is shown that the performance of the small sierra and coastal irrigation projects is consistently higher than that of the other projects in terms of their estimated contributions to the macroeconomic objectives of increased income and employment and foreign exchange generation. The medium and large projects appear to be less desirable investment choices for policy makers. Obviously, the above investment priorities can change to the extent that the weights attached to the national economic objectives also change. In any case, this type of adjustment can be incorporated easily into the ranking function.

Although the methodology developed in this paper was applied only to a set of irrigation projects in Peru, it is generally applicable to a wide variety of macroeconomic situations and projects.

References

[1] Chenery, Hollis B., "The Application of Investment Criteria," *Quart. J. Econ.* 67:76–96, Feb. 1953.

[2] Eckstein, Otto, *Water-Resource Development: The Economics of Project Evaluation*, Cambridge, Harvard University Press, 1958.

[3] Hydrotechnical Corporation, *Proyecto de Desarrollo de Tumbes: Estudio de Factibilidad*, Vols. 1–3, New York and Lima, Peru, 1965.

[4] ———, *Small Agricultural Developments: Arequina*, Vols. 1–4, New York and Lima, 1965.

[5] Instituto Nacional de Planificacion, Peru, *Plan de Desarrollo Economico y Social, 1967–70*, Vols. 1–4, Lima, 1967.

[6] International Engineering Company, *Estudio de Factibilidad del Proyecto Chira-Piura*, Vols. 1–2, Lima, 1967.

[7] ———, *Estudio de Factibilidad del Proyecto Choclacocha Desarrollado*, Vols. 1–3, Lima, 1966.

[8] Kalter, Robert J., and Thomas H. Stevens, "Resource Investments, Impact Distribution, and Evaluation Concepts," *Am. J. Agr. Econ.* 53:206–215, May 1971.

[9] Little, Ian M.D., and James A. Mirrlees, *Manual of Industrial Project Analysis in Developing Countries: Social Cost Benefit Analysis*, Vol. II, Paris, Development Centre of the Organisation for Economic Co-operation and Development, Development Centre Studies, 1969.

[10] Marglin, Stephen A., *Public Investment Criteria: Benefit-Cost Analysis for Planned Economic Growth*, Cambridge, The M.I.T. Press, 1968.

[11] McCreary-Karetsky Engineers, *Proyecto de Irrigacion de Moquequa: Informe de Factibilidad*, San Francisco and Lima, 1968.

[12] Theil, H., *Optimal Decision Rules for Government and Industry*, Amsterdam, North-Holland Publishing Company, 1964.

[13] Thorbecke, Erik, and A. Stoutjeskijk, *Employment and Output, A Methodology Applied to Peru and Guatemala*, Paris, Development Centre of the Organisation for Economic Co-operation and Development, Development Centre Studies, 1970.

[14] United Nations, Economic Commission for Latin America, *Manual on Economic Development Projects*, New York, 1958.

[15] van Eijk, C. J., and J. Sandee, "Quantitative Determination of an Optimum Economic Policy," *Econometrica* 27:1–13, Jan. 1959.

Estimated Net Costs of P.L. 480 Food Aid with Three Alternative U. S. Farm Programs*

Leo V. Mayer

Exports under P.L. 480 programs have become an established part of total demand for U.S. form output. Prices charged for commodities have varied with changing supply and demand conditions, but more recently terms of trade are being shifted in favor of the U.S. These changed terms of trade come at the same time the U.S. government is incurring increased costs for land diversion programs. This article reports research which simultaneously analyzes the two government programs, land diversion and P.L. 480 demand expansion, and provides estimates of the net cost per unit for specific commodities with three alternative land retirement programs.

Shipment of a sizeable portion of U.S. farm production to developing countries under P.L. 480 authorizations has now become a relatively permanent part of American farm policy. While stocks were plentiful in past years, few restraints, except lack of demand in recipient countries, were placed on shipments. As stocks reached more moderate levels in the mid-1960's, that policy was revised with temporary restraints placed on shipments until plans to increase acreage allotments or set asides could be implemented. With the temporary restraints on supplies came a hardening of terms for P.L. 480. Recipient countries were shifted from payment in local currency to payment in dollars. In addition, increasing amounts of cash type payments were generally required.

While dollar payments at concessional interest rates are spread over 20- and 40-year periods, net return to the United States on a present value basis is increasing as a whole. Whether or not this type adjustment is appropriate, given the changing supply situation, is the basic question of this paper. The approach is to estimate the net government cost per unit of food aid given (a) potential levels of food production from United States agriculture and (b) the estimated costs of government supply control programs.

Supply capacity, supply control, and food aid costs have been discussed earlier at some length. Schultz [5, p. 1023] suggested in 1960 that the "costs to the United States of P.L. 480 products measured in terms of marginal revenue foregone from foreign sales may have been zero, provided we treat our farm programs and agricultural production as constant." Tweeten [7, pp. 807–808] in a later article suggested a set of rules for pricing food aid ranging from transportation costs only "if U.S. farm output is excessive, if farm controls are objectionable, and if stocks are above realistic levels . . ." to usual commercial prices "if U.S. stocks are below normal and if production controls are not in effect. . . ." Both writers outlined decision rules for food aid without specifying the actual level of prices to be charged under various kinds of conditions.

The intent of this analysis is to measure the cost to the United States of food aid shipments through use of parametric programming. To do this, a programming model of the agricultural sector is used to derive shadow prices for delivering given quantities of wheat, feed grains, and cotton to recipient countries. The model is specified in a manner which takes into account alternative restrictive type farm programs that absorb cropland not presently required for crop or pasture production. Seven different levels of shipments are chosen and shadow prices derived for each level of shipment. Shipment costs are estimated for three different farm programs, including two types of long-term land retirement and an annual land retirement program. Finally, derived levels of shadow prices are transformed into indices to allow application to future pricing of food aid shipments given a particular type of farm program and a specified level of shipment.

Framework for Analysis

A linear programming model is used to simulate the production, marketing, and shipment of food to other countries. It is specified to account for two major alternative uses of production from cropland in excess of domestic and commercial export needs. One alternative

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Leo V. Mayer *is associate professor of economics and associate director of the Center for Agricultural and Rural Development at Iowa State University.*

is government programs that divert land resources from crop production. Use of government programs to reduce total crop output is now well established in the United States. Through a long series of public decisions, the nation developed a set of public programs to maintain prices and aggregate income levels of the agricultural sector. These programs annually retire several million acres of cropland. A second alternative use for cropland not used for domestic or commercial export production is production of agricultural output for shipment abroad under government programs. Shipment of a sizeable amount of total agricultural production abroad under P.L. 480 programs is also well established in the United States. This set of programs in its present form was first initiated in 1954 [9]. By the end of 1968, $17.6 billion of agricultural commodities had been exported [8, p. 97].

The linear programming model developed uses cropland as the major resource restraint. This resource forms a basic input in the crop production process and has been used as the major mechanism for controlling the aggregate supply of agricultural commodities. In the past, production units have had specific allotments for production of certain crops. When use of the national allotment resulted in over-production at supported price levels, the government purchased excess acres of allotment from the producer to reduce aggregate production.

In the past several decades the process of guaranteeing owners a market for land resources has in effect placed a two-way restraint on the land resources available for major crops. One restraint arises because, for any given level of technology, available cropland is limited. This restraint takes the traditional form

$$(1) \qquad x_1 + x_2 + \cdots + x_n \leq L,$$

where x_i represents the amount of land used in the production of crop $i (i = 1, \ldots, n)$ and L is total available cropland. Under conditions where land resources required for crop production are less than total land available, the inequality of this restraint holds and excess land resources remain idle.

With institutionalization of land use, marginal land resources are not forced out of crop production by market prices but are removed from production under government programs. This new type of relationship in resource use can be accounted for by defining an additional land using activity, r, and changing Equation (1) to

$$(2) \qquad x_1 + x_2 + \cdots + x_n + r_j = L,$$

where r_j is retirement of acres of cropland under the jth government program. Together, production and retirement activities must use all cropland available. If all land is required for crop production to meet potential demand, then retirement activities remain at zero level. If potential production exceeds demand, then retirement activities absorb the excess cropland.

Whether cropland is used for production of a crop or retired under the government program, there are associated costs. These costs may be expressed as

$$(3) \qquad C = \Sigma c_i x_i + c_j r_j$$

which specifies that each acre used for the ith crop costs c_i and each acre of cropland retired under the government program costs c_j. To derive a net cost of using cropland for production of the ith crop, Equation (2) can be solved for r_j and substituted into Equation (3) giving

$$(4) \qquad C = \Sigma c_i x_i + c_j(L - \Sigma x_i)$$

and total cost becomes a function of the total supply of land and total acres of crop production. Equation (4) can be rearranged as

$$(5) \qquad C = \Sigma(c_i - c_j)x_i + c_j L,$$

which denotes the net cost of each additional acre of x_i is the gross cost of one acre of crop production, c_i, less the total government cost, c_j, of retiring the same cropland. Thus, the net cost of producing an acre of crop i is $c_i - c_j$.

This concept of net cost outlined above[1] is used within the context of a parametric programming model to estimate the net cost of using marginal units of cropland for supplying food to other nations under P.L. 480 as opposed to retiring the cropland from production under government programs. Furthermore, it provides a basis for developing pricing policies for future food sales.

[1] For an explanation of opportunity cost in the linear programming framework, see [1, pp. 21–26]. The mathematical programming model used for this study has been built up over a period of years by Earl O. Heady and his associates (including the author) at Iowa State University. The author expresses his sincere appreciation to Professor Heady and his innumerable associates for the immense investment in time and effort which allows this kind of analysis to be made. Details of this particular model are available from the author.

Model Parameters

Several sets of parameters were estimated for the model. These included (a) output coefficients for each crop production activity for each of the 150 production areas into which the United States was divided; (b) cost coefficients for each activity in the model including crop production, land retirement, commodity substitutions, inland transportation, and international shipping; (c) cropland restraints for each region and crop included in the analysis, and (d) domestic and export demand levels for each commodity.

Output coefficients for each crop activity in each production area in which the crop is acclimated are estimated for 1970 using linear equations on post-1948 time series data for each state.[2] Activity costs were estimated for each crop in each production region. Production costs per acre included an allowance for power and machinery costs, labor requirement costs, fertilizer and seed costs, irrigation costs for water (if any), interest costs on operating capital, and drying and storage costs. Activity costs for transporting agricultural commodities —wheat, feed grains, and soybeans—between regions of the United States were based on railroad rates obtained from several sources [6, 8, 15]. All costs were measured in 1966 prices and reflect no allowance for inflationary changes that may have occurred through the projection year 1970.

Cropland restraints were based on historical harvested acreages of the crops included in the model, wheat, feed grains (including corn, oats, barley, and grain sorghum), soybeans, and cotton. These restraints were based on acreages harvested from 1952–54 when crop acreages were at recent maximums.

Total demand was divided into commercial utilization, including commercial export demand, and noncommercial demand or shipments under government programs. Domestic demand is estimated for 1970 based on domestic population size and average per capita consumption levels for direct consumption demand. Commercial export demand was estimated for 1970 based on trends of recent years. Commercial exports are defined as unassisted sales as well as those with government assistance in the form of (a) extension of credit and credit guarantees for relatively short periods, (b) sales of government-owned commodities at less than domestic market prices, and (c) export payments in cash or in kind.

Commercial export demand is held constant at the following levels: wheat, 300 million bushels; feed grains, 22.0 million tons; cotton, 1.5 million bales; and oilmeals, 12.2 million tons.[3]

Noncommercial export demand, representing P.L. 480 programs, was the major variable in the model. Demand from this source for each commodity, wheat, feed grains, and cotton, was varied from a zero level of shipments to a level in excess of past or expected levels of shipment. As each commodity was considered, demand levels for the other two commodities were set near recent levels. For example, when demand for wheat under P.L. 480 programs was varied from zero to 525 million bushels, demand for feed grains under these programs is set at 3.0 million tons and for cotton at 2.0 million bales, respectively. Other levels of P.L. 480 exports are shown in the section on results.

Analytical Procedure

Analytically, parametric programming was used to vary both demand levels for P.L. 480 shipments and activity costs for commodity purchase under government price support programs. Before commodities are shipped under government programs, however, considerable numbers of governmental decisions are required (Fig. 1). In the model, decisions in steps 1 through 3 of Figure 1 are prespecified, while steps 4 through 6 are internal to the model. In step 6, sales for domestic utilization are assumed to be zero and P.L. 480 demand is initially set at zero level for the specified commodity, followed by successive increases in quantities shipped under P.L. 480 programs. At each specified increase, estimates are derived of per unit costs of providing the marginal unit of the commodity. This per-unit cost measures the net cost of using cropland and other resources to produce the commodity for P.L. 480 programs, as compared with retiring the cropland (with other resources remaining

[2] For a more detailed explanation of methods used to derive model parameters, see [3].

[3] The assumption of a constant level of commercial exports raises some questions, as noted by one reviewer, (O. P. Blaich.) His point was that if P.L. 480 exports were varied, some offsetting changes would occur in commercial exports. The author agrees with this point but sees difficulty in fitting this type of change into the model without confounding the cause-effect nature of the results.

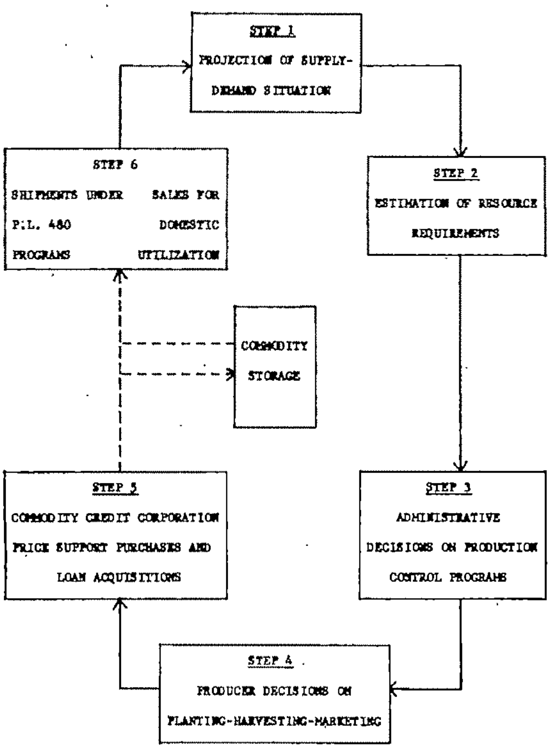

Figure 1. Decision-making processes for food and fiber.

idle) under government land retirement programs.

Parametric programming was also used to simulate government purchase of commodities at support prices. The usual minimum cost linear programming model selects activities to satisfy a given level of demand based on the criterion of least cost. As demand is increased, the cost for providing the marginal unit also increases. With this type of model, costs for supplying an increasing amount of a commodity for export would normally rise as more marginal production areas provide the additional units of production.

But the actual process by which commodities become available for P.L. 480 programs causes marginal and average costs per unit to be equal. That is, the price support mechanism sets a constant price for the purchase of all units, *1*, *2*, $\cdots$, *n*. To simulate this constant purchase price in the model, cost elements on shipping activities are varied parametrically as the quantity of commodities shipped under P.L. 480 programs increases. This process is shown in Figure 2 where the total cost (*tc*) of procurement and shipment of commodities under P.L. 480 is broken down into variable costs for producing each unit, a return to fixed factors used in production and costs for transportation, storage and shipping. The dotted line defines the support price (*sp*) of each commodity. In the model, cost coefficients on shipping activities are adjusted with each parametric increase in demand to simulate the difference between *pc* and *tc*. In this manner, a constant cost is simulated for producing, storing, and shipping a unit of the *j*th commodity. Total costs (*tc*) are taken from actual costs of operating P.L. 480 programs in the 1966–68 period. These data are given in Table 1 along with quantities shipped under P.L. 480 programs for 1966–68.

In summary, the parametric programming techniques used provide two types of simultaneous variation: one variation allowing a discrete change in the food aid demand vector; the second variation allowing for a discrete change in the shipping cost vector. The practical significance is that this combination of changes in the model allows simulation of real world conditions for production, government purchase, and eventual shipment of commodities to overseas destinations under P.L. 480 programs.

Estimated Government Food Shipment Costs

Estimated net government costs for providing specified quantities of wheat, feed grains, and cotton are reported in the next three sections. These estimated costs include the "savings" that result when cropland is no longer retired under a government program but instead

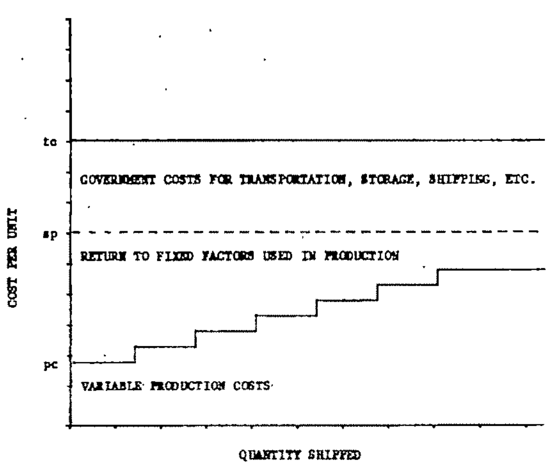

Figure 2. Cost structure for P.L. 480 commodities

Table 1. Quantities of major commodities and total and per-unit costs for commodities shipped under P.L. 480 programs, average for fiscal years 1966–68 [12–14]

Commodity	Average quantity shipped 1966–68[1]	Total and per-unit cost incurred for:				
		Commodity purchase	Ocean transportation	Export payment	Other costs	Total costs
Wheat	(Thousand bushels)[2]	(Thousand dollars)				
3-year average	373,403	636,843	63,977	91,404	65,995	858,219
cost per bushel	—	$1.71	0.17	0.24	0.18	2.30
Feed Grains	(Thousand tons)					
3-year average	2,598	130,997	16,620	—	31,958	179,573
cost per bushel[3]	—	$1.41	0.18	—	0.34	1.93
Cotton	(Bales)[4]					
3-year average	922,556	113,436	1.039	5,359	3,723	123,568
cost per pound	—	$0.256	0.002	0.012	0.008	0.279

[1] Includes all sales for foreign currency, sales for dollars on credit terms, and disposition under Title II except commodities in prepared form (rolled oats, rolled wheat, etc.).
[2] Bushels of 60 pounds.
[3] Costs per ton of corn, oats, barley, and grain sorghum converted into equivalent units of corn, 56 pound bushels.
[4] Bales of 480 pounds net weight.

is used to produce for shipment under P.L. 480 programs. Per-unit costs are derived for the marginal unit of production, that unit produced after domestic and commercial export demand is satisfied. The type of land retirement program is important because differences exist between programs for costs of retiring an acre of cropland.[4] Three types of land retirement programs are considered.

Long-term land retirement, no restrictions on location

Per-unit costs of wheat, feed grains and cotton for P.L. 480 programs are first estimated, assuming a long-term land retirement program. No restriction is placed on the proportion of acres retired in any production area; acres are retired in the most marginal areas of production with the program payment based on the estimated net return above all costs of crop production except land taxes.

Net costs per unit of commodity for each shipment level are specified in Table 2. At the initial level of 75 million bushels, wheat for P.L. 480 programs costs an estimated $1.40 per bushel. As shipments expand, cost per bushel rises. The cause of this increase is explained as follows: total government cost of purchase and shipment of a unit of a commodity is maintained at a constant level by the model. To hold this cost constant, the differential between the support price and production costs is reduced as the cost of producing a unit increases (Fig. 2). Consequently, since this cost is constant, the variation in cost results from the change in cost per acre of land retirement. As production is expanded, cropland returned to production has a lower net return and therefore a smaller cost for retiring it from production.[5] Hence, the increasing cost of each additional unit shipped under P.L. 480 results because the "savings" from removing this cropland from the government land retirement program diminishes. As this value declines, the net cost of each unit of food shipped increases.

The net cost of providing wheat in this economic environment increases to $2.01 when 525 million bushels of wheat are shipped, compared with a gross Commodity Credit Corporation (CCC) cost of $2.30 per bushel for the wheat shipped under P.L. 480 programs during 1966–

[4] Limitations on the amount of land retirement in any production area have been shown to have considerable effect on both the total cost of retiring cropland and the rural communities affected by the program. The latter grows out of the tendency for marginal cropland to be concentrated in particular area, i.e., the Great Plains and the southeastern states. For an analysis of this effect, see [2] and [4].

[5] The cost per acre of land retired increases as more and more acres are retired, since more productive cropland must be brought into the program with each increase. In reverse order, as crop production is expanded, the retirement cost per acre of land returned to production will decline. The "savings" from this source will decline, increasing the net cost per unit of food aid.

Table 2. Estimated net government cost per unit for commodities provided under P.L. 480 programs assuming the United States employs a long-term land retirement program with no restrictions on location

Recipient country or area	Level of P.L. 480 shipments[1]						
	1	2	3	4	5	6	7
Wheat (dollars per bushel)	1.40	1.60	1.71	1.74	1.80	1.89	2.01
Feed Grains (dollars per bushel)[2]	1.57	1.58	1.59	1.61	1.67	1.68	1.68
Cotton (cents per pound)	20.0	20.6	20.6	21.5	22.2	22.8	25.5

[1] Quantities are (million bushels wheat; million tons feed grains; million bales cotton):

Wheat	75	150	225	300	375	425	525
Feed Grains	1.5	3.0	4.5	6.0	7.5	9.0	10.5
Cotton	1.0	2.0	3.0	5.0	5.0	6.0	7.0

[2] Feed grain price is per bushel of corn or equivalent nutritive value of other feed grain.

68 (Table 1). The increase from $1.40 at 75 million bushels of wheat to $2.01 at 525 million bushels indicates the magnitude of decrease in land retirement costs as shipments of wheat are increased.

The net cost of feed grains is estimated at $1.57 per bushel of corn when 1.5 million tons are shipped and rises to $1.68 when a total of 10.5 million tons are shipped.[6] This cost compares with an average total CCC cost of $1.93 per bushel incurred for feed grains shipped for the years 1966–68. The small change in net cost per bushel of feed grains indicates the cost of land retirement remains relatively constant over this magnitude of change in acreages harvested. One reason for this is the relatively small size of feed grain shipments. Even at the maximum level, 10.5 million tons, less than 6 percent of total feed grain production would be exported under P.L. 480 programs.

The net cost of cotton ranges from $0.20 per pound for 1.0 million bales of cotton to $0.25 per pound for 7.0 million bales. This compares with an average cost of $0.279 per pound for shipments from 1966 through 1968. The greater percentage rise in cost per unit of cotton than for feed grains indicates the cost of land retirement in cotton areas varies over a wider range than it does in feed grain areas. Also, the 7.0 million bales of cotton represent 40 percent of total production. This level is well in excess of recent levels of cotton exports under P.L. 480 programs. It would require nearly all land available for cotton returned to production. At this point almost no savings would be realized from reduced land retirement, and hence, the cost of cotton per pound of lint approaches the gross cost of these shipments.

[6] Feed grains prices are measured in terms of corn, although other kinds of feed grains may be shipped.

Long-term land retirement, with restrictions on location

A second type of government program examined would ship the same quantities of wheat, feed grains, and cotton lint with this limitation placed on the land retirement program: no more than 50 percent of total cropland can be retired in any production region. Acres retired are spread over more productive areas; these acres have a higher net return from crop production (and a higher cost for retirement). Consequently, the cost of retirement is higher at each level of shipment, but this results in a lower cost (compared with the previous program) per unit of commodity.

Estimates of net cost per unit of wheat, feed grains, and cotton are specified in Table 3. The net cost of wheat is $1.29 per bushel (compared with $1.40 with the previous program) with shipments of 75 million bushels. As shipments expand, the cost per bushel increases and reaches $1.71 at 525 million bushels.

Feed grain costs are lower than those in the previous model, increasing from $1.43 per bushel to $1.57 per bushel as shipments increased from 1.5 million to 10.5 million tons. Costs for cotton for this type of program rose from $0.189 per pound to $0.234 per pound.

Costs of cotton under P.L. 480 programs have a somewhat different composition than costs of wheat or feed grains. Transportation and other costs for cotton are a smaller proportion of total costs than for other commodities. Wheat costs in 1966–68 were broken down as 74.3 percent commodity purchase and 25.7 percent transportation and other costs.

Table 3. **Estimated net government cost per unit of commodities provided under P.L. 480 programs assuming the United States employs a long-range retirement program with a 50 percent limit on retirement in any production area**

Recipient country or area	Level of P.L. 480 shipments[1]						
	1	2	3	4	5	6	7
Wheat (dollars per bushel)	1.29	1.34	1.47	1.59	1.59	1.61	1.71
Feed Grains (dollars per bushel)[2]	1.43	1.46	1.48	1.49	1.56	1.56	1.57
Cotton (cents per pound)	18.6	20.0	20.0	20.6	20.6	21.4	23.4

[1] Shipment levels are the same as shown in Table 2.
[2] Feed grain price is per bushel of corn or equivalent nutritive value of other feed grain.

Feed grains costs were similar with commodity purchase accounting for 73.1 percent of total costs per unit. But cotton has a lower proportion of costs for transportation and other items. For cotton, 91.8 percent of all costs in 1966–68 were for commodity purchase and only 8.2 percent for transportation, export payments, and other costs. The lower percentage of costs for these other items in the case of cotton results primarily because support prices for cotton are competitive with world market prices. Only minor export payments are required for sale of cotton under P.L. 480 programs. In addition, costs for transportation for all commodities have been reduced because "an amendment to Public Law 480 signed October 8, 1964, included a provision eliminating local currency financing of ocean transportation in U. S. flag vessels. Now only the differential between U. S. and foreign flags rates is paid by CCC where commodities are required to be transported in U. S. vessels" [10].

Annual land retirement—direct payment type programs

The final analysis assumes land retirement programs that individually retire cropland from wheat, feed grains, and cotton on an annual basis with direct payments to producers on a portion of production as an incentive to participate. This program was based on actual cost figures from programs in effect for these crops in 1966 [11].

Cost per retired acre is higher than in the previous programs. These higher costs result primarily because under an annual program producers have a tendency to retain all factors of production (land, labor, and capital items) necessary to operate their firms at full capacity. Retaining these factors of production results in producers' incurring fixed costs for depreciation and underemployed labor. Payments for land retirement must cover these costs to gain participation of producers. Hence, payments per acre for this type of program will be larger than those for a long-range program under which excess factors of production can be sold and excess labor employed elsewhere.

Costs of P.L. 480 programs for wheat and other commodities with this type of land retirement program in effect are given in Table 4. The first 75 million bushels of wheat are estimated to cost $0.08 per bushel. Costs rise with shipments. At 150 million bushels, cost is $0.50 per bushel. At the maximum level considered, 525 million bushels, the net cost per bushel is $1.31. These data indicate the net cost of wheat shipments under P.L. 480 pro-

Table 4. **Estimated net government cost per unit for commodities under P.L. 480 programs assuming the United States employs annual land retirement programs for wheat, feed grains, and cotton**

Recipient country or area	Level of P.L. 480 shipments[1]						
	1	2	3	4	5	6	7
Wheat (dollars per bushel)	0.08	0.50	0.87	1.05	1.13	1.27	1.31
Feed Grains (dollars per bushel)[2]	1.08	1.10	1.15	1.17	1.32	1.34	1.34
Cotton (cents per pound)	13.8	16.8	17.2	17.2	17.7	18.2	19.2

[1] Shipment levels are the same as shown in Table 2.
[2] Feed grain price is per bushel of corn or equivalent nutritive value of other feed grain.

grams is relatively low when measured against the high cost of retiring land under this type of program. Likewise, these costs indicate shipments of wheat have a much lower net cost than gross costs incurred by CCC would suggest. While the gross cost for each bushel of wheat shipped under P.L. 480 in 1966–68 was $2.30, there is a clear indication that retiring these same acres would have cost nearly as much had these shipments not been made, particularly for the initial 75 million bushels. At the average level of shipment for 1966–68, 373.4 million bushels, the average net cost is estimated at $1.13 per bushel, approximately 49 percent of the gross cost of shipments.

Estimated costs for feed grain shipments with annual land retirement programs are lower than for either program considered previously, although not as significantly as for wheat. At an initial level of 1.5 million tons, the cost is estimated at $1.08 per bushel, approximately 75 percent of the previous program. As shipments increase, costs per bushel increase, reaching $1.34 per bushel at 10.5 million tons of feed grains.

The net costs of cotton shipped are also lower for this type of program. Cotton costs at 1.0 million bales are estimated to be 13.8 cents per pound of cotton lint, 73 percent of the previous program cost. As shipments expand, costs increase, reaching 19.2 cents per pound of lint at 7.0 million bales. The estimated costs of P.L. 480 programs for all commodities considered with this type of land retirement program are considerably lower than for the previous programs.

Guidelines for Pricing P.L. 480 Commodities

The estimated per-unit government cost of P.L. 480 shipments specified for each alternative land retirement program above is based on actual costs incurred for commodities programmed under these programs during 1966–68 and estimated costs for each type of land retirement program. These costs are subject to change over time due to changes in price support levels, proportion of international transportation costs borne by the CCC, and world prices of these commodities. The world price determines to a large extent the level of export subsidy necessary to make these commodities competitive in export markets. Since these costs are specific to a past period, an attempt is made below to make these estimated costs more applicable to future pricing of P.L. 480 commodities.

To develop this type of guideline for pricing future shipments, the estimated net average cost for commodities for each alternative land retirement program is compared with the gross CCC costs for the period 1966–68. This ratio,

$$(7) \quad \frac{\text{Estimated Net Cost}}{\text{Gross CCC cost}}(100) = \text{Pricing Coefficient}$$

provides an estimate of the percentage of gross costs to be charged for P.L. 480 shipments, given (a) the type of land retirement program actually in use at a particular time and (b) the actual CCC costs of food aid commodities.

Pricing coefficients are summarized in Table 5 for the three types of land retirement programs examined. They vary according to the level of shipment, the particular commodity shipped, and the land retirement program. For wheat, the pricing coefficient varies from 3.5, with an annual land retirement program and a shipment of 75 million bushels of wheat, to 87.4, with a long-range retirement program and 525 million bushels. The pricing coefficients for annual programs are considerably lower for all levels for wheat shipments than for other programs.

The pricing coefficients for feed grains and cotton are generally higher than for wheat for a similar shipment level and land retirement program. These results suggest, given the criteria explained earlier, that shipments of feed grains are optimally priced if the return is 81.3 percent of the CCC cost when 1.5 million tons are shipped and a long-range land retirement program is used to control aggregate production. For the same level of shipment, feed grains shipments priced at 56.0 percent of their CCC cost are optimal if annual programs with direct payments are used to control production. For these respective programs, these percentages rise to 87.0 percent and 69.4 percent of CCC costs at the maximum level of shipments.

For cotton the estimated net cost of a 1.0 million-bale shipment varies from 74.6 percent of CCC costs with a long-range land retirement program to 51.5 percent with an annual land retirement program. These coefficients increase to 95.1 with the long-range program when 7.0 million bales are shipped and 71.6 when annual

Table 5. Estimated net costs as a percentage of gross CCC costs for P.L. 480 shipments of wheat, feed grains, and cotton during 1966–68, under alternative supply control programs

Type of land retirement program	Level of P.L. 480 shipments						
	1	2	3	4	5	6	7
				Wheat			
Long-range retirement No restrictions	60.9	69.6	74.3	75.7	78.3	82.2	87.4
Long-range retirement 50 percent restrictions	56.1	58.3	63.9	69.1	69.1	70.0	74.3
Annual land retirement Direct payments	3.5	21.7	37.8	45.7	49.1	55.2	57.0
				Feed Grains			
Long-range retirement No restrictions	81.3	81.9	82.4	83.4	86.5	87.0	87.0
Long-range retirement 50 percent restrictions	74.1	75.6	76.7	77.2	80.0	80.0	81.3
Annual land retirement Direct payments	56.0	57.0	59.6	60.6	68.4	69.4	69.4
				Cotton			
Long-range retirement No restrictions	74.6	76.9	76.9	80.2	82.8	85.1	95.1
Long-range retirement 50 percent restrictions	70.5	74.6	74.6	76.9	76.9	79.8	87.3
Annual land retirement Direct payments	51.5	62.7	64.2	64.2	66.0	67.9	71.6

programs are used with this level of shipment. During the period 1966–68, an average of 1.0 million bales of cotton were programmed for shipment to recipient countries under P.L. 480 programs.

To conclude this discussion on pricing levels and provide comparisons with actual data, the actual levels of cost recovery were calculated for commodities programmed for shipment between 1966–68. While data are not available for the individual commodities as might be preferred, data are available on the proportion of gross CCC costs recovered in contracts signed between 1966 and 1968. To calculate these proportions the estimated export market value of P.L. 480 shipments is compared with the CCC costs of these shipments. These results indicate a sharply rising trend after 1965. From a level of 60 percent in 1965, the level of cost recovery rose to 69.5 in 1966, to 80.9 in 1967, and 84.7 in 1968.

To test these recovery rates against those that would exist if the pricing levels derived earlier in this study were used, the level of recovery with the concept of net cost applied to pricing was calculated for wheat, feed grains, and cotton. For these estimates, pricing coefficients from Table 5 were weighted with the proportion of wheat, feed grains, and cotton actually programmed for shipment in each year between 1966 and 1968. The following comparisons were derived:

	Estimated	Actual
1966	54.9	69.5
1967	50.0	80.9
1968	39.4	84.7

The proportions derived using results of this analysis are below the actual levels of cost recovery. As costs for land retirement rose in 1967 and 1968, the net costs of potential food shipments declined. Actual recovery rates went up, however.

Conclusions

The empirical results of this study indicate the net government cost of U. S. food shipments is considerably lower than gross CCC costs would suggest. These cost estimates provide a "lower bound" for pricing future quantities of commodities since, of course, any lower return would mean the United States could manage its agricultural capacity in a cheaper manner by retiring the land instead of producing and shipping the commodities. In contrast, an "upper bound" is established by the gross CCC costs for these commodities, and this price level would be relevant if the alternative use for agricultural resources was idleness with zero

cost, or even alternative employment.

Given the empirical results and the pricing considerations outlined, the following conclusions can be drawn:

1. For the time interval during which the U. S. continues to rely upon a policy of using all its institutionalized land resources for either crop production or government-supported land retirement, the appropriate level of costing for P.L. 480 products is considerably below gross CCC costs. Given continued extensions of annual land retirement programs, pricing for food aid programs should be re-evaluated.

2. The major benefit of such a policy change accrues to the recipient nations who would require reduced amounts of long-term credit. The realities are probably such that many countries will eventually find present prices and associated credit terms a heavy burden on limited foreign earnings.

3. Finally, the objective of aid-in-kind should always be kept in mind. Such aid must have as its goal an improvement in welfare of recipient nations' consumers, both in the short term through consumption of food and in the long term through positive effects on economic development. To the extent that food shipments represent a larger proportion of aid-in-kind and a smaller proportion of commercial sales for credit, recipient nations may be genuinely helped to improve the lot of their poorer strata of consumers.

References

[1] HEADY, EARL O., AND WILFRED CANDLER, *Linear Programming Methods*, Ames, Iowa State University Press, 1958.

[2] ———, AND NORMAN K. WHITTLESEY, *A Programming Analysis of Interregional Competition and Surplus Capacity of American Agriculture*, Iowa Agr. Exp. Sta. Res. Bull. 538, July 1965.

[3] MAYER, LEO V., AND EARL O. HEADY, *Projected State and Regional Resource Requirements for Agriculture in the United States in 1980*, Iowa Agr. Exp. Sta. Res. Bull. 568, June 1969.

[4] ———, EARL O. HEADY, AND H. C. MADSEN, *Farm Programs for the 1970's*, Center for Agr. and Econ. Dev. CAED Rep. 32, Iowa State University, 1968.

[5] SCHULTZ, THEODORE W., "Value of U. S. Farm Surpluses to Underdeveloped Countries," *J. Farm Econ.* 42:1019–1030, Dec. 1960.

[6] SKOLD, MELVIN D., "Programming Regional Adjustments in Grain Production to Meet Changing Demand," unpublished Ph.D. thesis, Iowa State University, 1963.

[7] TWEETEN, LUTHER G., "A Proposed Allocative Mechanism for U. S. Food Aid," *J. Farm Econ.* 43:803–810, Nov. 1966.

[8] ULREY, IVON W., "The Economics of Farm Products Transportation," ERS Market. Res. Rep. 843, 1969.

[9] U. S. Congress, *Agricultural Trade Development and Assistance Act of 1954*, Public Law 480, Chap. 469, 83rd Cong., 2nd sess., 1954.

[10] ———, *1964 Annual Report on Public Law 480*, H. Doc. 130, 89th Cong., 1st sess., 1965.

[11] U. S. Department of Agriculture, ASCS, *1966 Feed Grain and Wheat Programs, Statistical Summary*, 1967.

[12] ———, Commodity Credit Corporation, *Report of Financial Conditions and Operation, June 30 Quarterly Report*, Sept. 1966.

[13] ———, CCC, *Report of Financial Conditions and Operation, June 30 Quarterly Report*, Sept. 1967.

[14] ———, CCC, *Report of Financial Conditions and Operation, June 30 Quarterly Report*, Sept. 1968.

[15] WRIGHT, BRUCE H., private communications, Iowa State University, 1968.

Michigan Food Stamp Program: A Partial Analysis of Performance*

Paul E. Nelson, Jr.

Models were developed and applied to explain the sources of flow of participants into the Michigan Food Stamp Program and to determine if the program influenced participants in their choice of store for purchasing food with their stamps. Subsidiary questions considered were the determination of the contribution to total sales tax receipts of participating counties which might be attributed to purchases where payments were made with food stamps and the extent to which the food stamp program might have determined where participants purchased their groceries.

Congress maintains constant scrutiny over all federal programs by requiring continuous reporting. Recent developments suggest that the USDA Food and Nutrition Service prefers emphasis on the quantitative approach in its performance reports. For instance, the service has instituted means for providing data[1] to interested scholars as well as commissioning specific research.

The Michigan Program

During its first five years, the Michigan Food Stamp Program experienced rapid growth. The number of participants jumped from 60,949 in 1966 to 197,988 by 1970. In the participating counties the proportion of the total population taking part in this program rose from 1.5 to 2.4 percent, a rise of almost 60 percent.

This growth was also reflected in dollars. In 1966 the value of *total* stamps issued was $12.4 million. By 1970 it was $43.2 million, an increase of about 249 percent. Simultaneously, the total sales of retail food stores within the participating counties grew by $2,797.5 million, 131 percent. Growth in total retail sales was associated with both increased quantities purchased and inflation. The growth in the value of the stamps, however, primarily reflected increased numbers of participants. The mean value of food stamps issued each participant was $203 in 1966. By 1970 it was $218, a rise of 7 percent.

Focus of report

Much research is needed to provide answers to questions associated with factors which might influence eligible persons to become program participants[2] and to those relating to major impacts of the Michigan Food Stamp Program upon participating counties. However, this report limits itself to the following questions:

(1) To what extent did the participants in the Michigan Food Stamp Program come from groups such as workers engaged in labor-management disputes, interstate migrant workers, university married students, and the unemployed?

(2) Did counties with low disposable personal income levels have a greater proportion of their population participate in the program than did counties with higher levels?

(3) Did supermarkets gain more from the expenditures of food stamps than did stores with less than $500,000 in sales per annum?

(4) For participating counties, what was the contribution to the Michigan sales tax obtained from the sales paid for by the food stamps?

Methodology

The major participation questions were answered by the regression coefficients of one model. Subsidiary questions were answered by Chi-square, contingency coefficient, and correlation comparisons.

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[1] Aggregated prior to transmission to avoid disclosure. In this paper all food stamp program data were supplied in unpublished form by the Food and Nutrition Service.

[2] Readers interested in a study of persons who dropped out of a food stamp program and the reasons for their actions are referred to [3].

Paul E. Nelson, Jr. *was visiting professor of agricultural economics at Michigan State University January–June 1971 while on leave from ERS, USDA.*

The data series were obtained from the continuing records of the firms and agencies listed in footnote *. They were either reported on a fiscal year basis or changed to one. All data were on a county basis. For a few counties labor series data were estimated for 1967. Estimates took into account the reports of neighboring counties in that year, the state and upper peninsula averages, and comparable county business pattern data. In a few instances where data were provided on a labor market basis, the three or four counties composing such a market were disaggregated using ratios from county business patterns.

The model used multiple regressions which combined times series and cross section data. In essence these multiple regressions represented an analysis of covariance [1, 2, 5, 6].

Who participated?

Choice of variables.—When constructing a model to explain the number of participants in the food stamp program, many variables appeared logical either from an economic or an institutional basis. Certain groups came to mind naturally. These included many of the disabled and indigent. All shared the common characteristic of low disposable personal income, a program eligibility requirement. Specifically, such groups with numerous members who possessed eligibility were reflected in the social and economic statistics readily available. Examples included recipients of public assistance program payments, the unemployed, interstate migrant workers, persons engaged in labor-management disputes, and married students.

In addition, some characteristics of participating counties merited special recognition. For instance, counties differed in the extent to which they had conducted public food distribution programs. Counties with a history of commodity distribution programs were more experienced than counties which had not. Thus, a dummy variable was constructed to reflect whether a county had such experience.

Counties also differed in their social and economic characteristics. Counties like Wayne, Oakland, and Macomb were not mirror images of upper peninsula counties like Schoolcraft. To permit all such differences to reflect themselves, a dummy variable was created for each participating county but Alger. In essence all counties were compared with Alger.

These two sets of dummy variables created a problem. The dummy which represented prior experience with the commodity distribution program was a subset of the county dummies for participating counties. "Singularity of the matrix" would have resulted if both dummies had been included in the same model. Hence, two comparisons were conducted to ascertain which was the better dummy to include.

The use of county dummies appeared to distort the regression coefficients that were checked from sources external to the model. For instance, the regression coefficient of the variable, the number of recipients in the public assistance programs of Michigan, was in close agreement with the results of an independent study [4] when the commodity distribution experience dummy was used, but not when the county dummies were adopted. Moreover, it appeared unlikely that *all* migrant workers (many of whom did not have their families with them) joined the food stamp program. Indirect evidence in the form of conversations with workers associated with the food stamp program supported this belief. Participation was marked but not complete. Yet, with the county dummies, the regression coefficient indicated that each added migrant worker added 1.2 participants to the stamp program.

Because the dependent variable was the number of food stamp participants, the use of the dummy variable which indicated a county's prior experience with a commodity distribution program appeared particularly appropriate. It was believed that such experience would help boost initial participation in a new food stamp program. Public acceptance of a new food program and the probable greater facility of administration of the new program were among the reasons for this belief. For these reasons the prior experience dummy was used.

Except for the Bureau of Labor Statistics-Consumer Price Index (BLS-CPI) all variables were cast upon a county basis. The CPI was adopted to minimize secular trend and to reflect any association between inflation and participation. Persons on relatively stable incomes who under inflation might find themselves newly eligible under revised income restraints could decide to participate. Comparisons of the Detroit and Minneapolis-St. Paul series showed the Detroit series could be used to represent both the upper and the lower peninsulas.

Disposable personal income was deliberately excluded from the independent variables. Not

only was the low disposable personal income reflected in the eligibility rules for participation, but also a preliminary comparison showed extremely high intercorrelation with other independent variables. This was expected since recipients of public assistance payments, the unemployed, and migrant workers generally were groups with low disposable personal incomes.

The model

The dependent variable was the number of participants in the food stamp program in the ith county, time t. Independent variables fitted into any of three categories: (1) variables which were constant over t but varied over i, here, Z_1^{it}—Z_5^{it}; (2) variables which varied over t but constant over i, here, L^t; and (3) variables which varied over both t and i, here, N^i. Thus,

$$Y^{it} = a + \sum_{k=1}^{5} b_k Z_k^{it} + cL^t + dN^i + e^{it}$$

Where:

Y^{it} = Number of food stamp participants
a = a general constant
Z_1^{it} = Mean monthly unemployment
Z_2^{it} = Mean monthly workers engaged in labor-management disputes
Z_3^{it} = Number of married students
Z_4^{it} = Number of recipients of Michigan public assistance programs
Z_5^{it} = Mean monthly interstate migrant workers
L^t = BLS-CPI
N^i = Commodity distribution prior to food stamp program dummy
b_k, c, and d = Coefficients
e^{it} = Random disturbance.

Results

General context

Table 1 presents the simple correlations among the independent variables. There was no evident problem arising from high intercorrelations among these variables. However, some of these relationships require comments, for instance the association (0.761) between the mean monthly number of the unemployed and

Table 1. Comparisons of simple correlation coefficients among independent variables

Variable	BLS-CPI [Detroit]	Counties with a commodity distribution program prior to food stamp program	Mean monthly number of unemployed	Mean monthly number workers in labor-management disputes	Mean monthly number interstate migrant workers	Number married students	Number recipients of public assistance payments
BLS-CPI [Detroit]	1.0	0.000	0.112	0.160	0.075	0.044	0.082
County with commodity distribution program prior to food stamp program	0.617	1.0	0.276	0.258	0.117	0.214	0.201
Mean monthly number unemployed	0.112	−0.257	1.0	0.761	−0.003	0.580	0.826
Mean monthly number of workers in labor-management disputes	0.160	−0.141	0.761	1.0	0.006	0.437	0.533
Mean monthly number of interstate migrant workers	0.075	−0.231	−0.003	0.006	1.0	−0.067	0.014
Number married students	0.044	−0.252	0.580	0.437	−0.067	1.0	0.536
Number of recipients of public assistance payments							1.0

Table 2. Comparisons of multiple regression and multiple and simple correlation results

Variable Y^{ii}=Number of participants in the food stamp program	Simple r's years with program	Regression coefficients	Standard errors	t[a] value
BLS-CPI [Detroit]	0.110	8.70	17.42	0.4994
County with a direct commodity distribution program prior to food stamp program	0.00	661.91	221.81	2.9842
Mean monthly number of unemployed	0.966	0.7854	0.0302	25.9755
Mean monthly number of workers engaged in labor-management disputes	0.680	−0.6061	0.1592	−3.8071
Mean monthly number of interstate migrant workers	0.028	0.6246	0.2276	2.7445
Married students	0.565	−0.0169	0.0406	−0.4171
Number of recipients of public assistance programs	0.891	0.1926	0.0171	11.2527

$R=0.9820$, $\bar{R}=0.9815$, $R^2=0.9644$, $\bar{R}^2=0.9633$

[a] Any t value of 1.645 or above is statistically significant at least at the 5 percent level.

mean monthly number of workers in labor-management disputes. In Michigan the unemployment statistic *by definition* excludes all workers on strike. However, strikes can cause non-striking plants to close, their workers then becoming unemployed. In contrast, the association between the number of recipients of public assistance payments and the number of married students (0.536) was without analytical content. In Michigan married students simply were (and are) not eligible to receive such payments.

For each county plots (against time) of the difference between the observed Y and estimated Y were scrutinized to determine if serial correlation of the dependent variable was a problem. It was not. Similar type plots were made to test for heteroscedasticity and for serial correlation among independent variables. Nothing substantial was found.

Regression coefficients

Table 2 presents the multiple regressions coefficients, their standard errors (SE), the relevant t values, multiple coefficients of correlation and determination (R, R^2) uncorrected. The multiple coefficient of determination corrected for degrees of freedom ($\bar{R}^2$) explained 96.3 percent of the variation in the number of participants for the period fiscal 1967 through fiscal 1970.

Unemployment was a primary source of participants. For each 10 additional unemployed persons, the food stamp program gained almost 8 participants. Some of the participants, of course, were family members of the unemployed. Of all the variables considered, unemployment was the most significant.

The public assistance programs were second in order of significance. During the study period, for every 10 new recipients of public assistance payments, the food stamp program gained 1.9 additional participants. This figure corresponds closely to a figure of 2 reported by Peterson [4]. His study covered only adult programs in 1970.

The coefficient of the striking workers variable was negative. This was unexpected. In a simple relationship between the number of participants in the program and the number of workers on strike the coefficient is expected to be positive. Indeed, it is here with an r of 0.68. Why, then, is the sign negative? There are several possibilities. Among the most likely are (1) a relatively high intercorrelation between one or more variables; (2) both the independent variable and the dependent variable in question are highly correlated with a third variable, often not in the model, and (3) the model may be misspecified.

The relatively high simple correlation between the number of workers on strike and the number of unemployed workers (0.76) could account for the negative sign, but the other

two sources seem more likely. While both economic theory and known institutional relationships were relied upon to construct the model prior to making the regression comparisons and while the $\bar{R}^2$ is 0.96, a missing variable could account for the negative sign. However, most likely is the fact that both the dependent variable (number of participants) and workers on strike are correlated with a third variable.

Certain facts about Michigan labor statistics support this as the most likely explanation. The Michigan labor series exclude workers on strike from unemployment statistics, although both groups are subsets of the work force statistic. However, workers who became unemployed when their plants closed because they could neither sell to nor buy from struck plants (or both) *are* included in the total unemployment figure.

This statistical circumstance provides the basis for the rather lengthy explanation in Appendix A.[3] If this explanation is correct, then the suggested interpretation for the coefficient of workers on strike is that whenever 10 additional workers became strikers, the food stamp program gained about 6 participants, which included family members of workers as well as the workers themselves.

This ratio need not hold for a period when the strikers return to work. For instance, it is possible that some workers may find they have been replaced by new and/or added pieces of equipment. Also, any redefinition of the stamp program's income eligibility standard could mean either fewer or more workers would remain eligible for participation than during the pre-strike period.

Counties with prior commodity distribution programs on the average added about 662 more participants than did counties without such a history. This relationship should weaken rather rapidly over time; at least in Michigan, it was of importance for the first five years of the stamp program.

For every 10 additional interstate migrant workers, the program gained about six new participants. This proportion seems to reflect seasonality, family structure, and the rates of renumeration generic to this type of work.

The regression coefficient for the BLS-CPI was not statistically significant. In fact, the t value was so low that the absolute value of the coefficient was probably quite meaningless in terms of operational importance. The sign supported the original hypothesis that an upward movement in the index could result in the addition of persons to the program.

The married student regression coefficient had the lowest t value. In fact, this coefficient could have occurred by chance 58 times out of 100. With the value of both the coefficient and the t value so low, it was not surprising to find a negative sign. Signs often "flip" in such situations. The absolute value of the regression coefficient was analytically useless. However, the fact that the coefficients were so low is of importance. Much public attention has been given to purported married student participation in the stamp program. However, the data did not include information about unmarried students. Eligible unmarried students could form a "household" and be eligible for stamps as a "group." These results cannot reject the possibility that unmarried students and "unmarried households" participated more than married students. Michigan recently adopted changes that will prevent such participation in the future.

Low disposable income and level of participation

Because disposable income was excluded as an explicit variable in the model, two separate tests of its relative importance in explaining participation were made. The first test utilized Chi-square and contingency coefficients, while the second test applied a product moment method correlation. Test results were consistent.

Specifically, did counties with low mean disposable personal incomes have a strong association with the number of participants in the food stamp program? Table 3 presents the results of the test of the following hypothesis: there is no difference among counties with greater than the combined median per capita disposable income and counties with equal to or less than this median, in the number of counties within each category which had greater than the combined median number of food stamp program participants.

For all years but 1967, the difference between counties with greater than the combined median per capita personal disposable income and counties with equal to or less than this median income was sufficiently great to be statistically significant. In 1967 the χ^2 that was

[3] I wish to thank Professors Manderscheid and Gustafson for the suggestion and elaboration of this point.

Table 3. Results of Chi-square,[a] contingency coefficient,[b] and product moment method correlation[b] comparisons

Year	χ^2	C_t	$PMMr$	$PMMr^2$
1967	2.143	0.3536	0.3780	0.1076
1968	8.242	0.5714	0.6963	0.4844
1969	12.216	0.4884	0.5596	0.3136
1970	4.846	0.3057	0.3211	0.1030

[a] Any reported χ^2 value of 3.840 or above is statistically significant at the 5 percent level.

[b] Any C_t where associated with a χ^2 value of 3.84 or above also is statistically significant at the 5 percent level. For 1 degree of freedom, which prevailed for these comparisons, the value of C_t had a possible range of 0 to -0.7. The $PMMr$ range was from -1.0 to $+1.0$.

computed could have occurred by chance about 15 times out of 100.

The coefficient of determination indicating the extent to which differences between categories were associated with differences in per capita income ranged from about 10 percent in 1967 to 48 percent in 1968. These results supported the idea that the level of per capita disposable income was important. When a county had less than the combined median disposable income, it tended to have greater than the median number of food stamp program participants.

Purchase impact upon kind of food store

Another model was developed to show how a change in the gross per capita sales through retail food stores was associated with a change in the dollar value of food stamps issued each participant during the 1967–70 period and by the support by the total program. A related but different question concerned the kind of food store patronized by food stamp program participants. Did participants favor supermarkets or did they favor stores whose sales were less than $500,000 per annum?[4]

The author's hypothesis was that food stamp program participants were more likely to be captives of their "geography of residence" than were more affluent consumers, who would have access to "wheels" to enlarge their range of shopping activities.

A definitive answer would have required the records of redemptions by store, each store's size, and the type of organization identified. Such information was not available.[5]

The following comparisons and their results, as reported in Table 4, provide some insight. Participating counties were divided into two categories: (1) counties in which supermarkets had greater than 50 percent of the total sales reported for all retail food stores, and (2) counties in which supermarket sales were equal to or below 50 percent of the total retail food store sales. Both categories, of course, had supermarkets and stores with less than $500,000 in annual sales.

If the retail per capita sale of supermarkets

[4] During the years with the food stamp program, each recipient of Michigan public assistance payments had an r of 0.133 for his association with supermarket sales and one of -0.038 for his association with sales of stores of smaller size. The gross correlation between total Michigan public assistance payments and supermarket sales was 0.138 and between it and sales of stores below supermarket size was -0.028. This evidence suggested that participants in the food stamp program might be more likely to redeem their stamps in supermarkets than in smaller stores. Hence, the comparisons discussed here were made to test this possibility further.

[5] These results must be considered suggestive rather than definitive. Only the Food and Nutrition Service has the information required to make a definitive test of this association. The service could not transmit the desired data because of agreements with the trade concerning disclosures.

Table 4. Multiple regression and correlation results of comparisons of per capita sales through supermarkets and all other retail food stores and the food stamp program

County category	Store category	Regression coefficients	Standard errors	t	Level of significance	R	$\bar{R}$	R^2	$\bar{R}^2$
Greater than 50 percent of total retail sales by supermarkets	Supermarkets	506.38	332.83	1.5214	0.1300	0.3912	0.3673	0.1531	0.1349
	All others	−32.84	248.93	−0.1319	0.8950	0.2338	0.1856	0.0547	0.0344
50 percent or less by supermarkets	Supermarkets	−669.63	805.90	−0.8309	0.4120	0.2528	0.0000	0.0639	0.0569
	All others	394.08	426.55	0.1091	0.9140	0.1203	0.0000	0.0145	0.0113

were to gain more than did the per capita sales of stores of smaller size *in both categories of counties*, there would be *some* evidence for suspecting the food stamp program had influenced the store patronage patterns of participants. If, to the contrary, the gains in per capita supermarket sales were to hold for only one of the two categories, then it would appear likely that the food stamp program was neutral, i.e., without marked influence upon patronage patterns.

Thus, within each structural category two sets of regressions were computed. The dependent variable of the first regression was the per capita sales of supermarkets and of the second regression those sales of stores of less than $500,000 sales per year. The independent variables were the same for both sets of comparisons. One variable was the proportion of food stamp participants in the ith county's total population in year t, and the second was the BLS-CPI for the year in question. The results for counties which had more than 50 percent supermarket sales showed that for every 1 percent increase in the proportion of food stamp participants in total population in the ith county, the supermarket per capita sale increased by $5.06. This regression coefficient could have occurred by chance 13 times out of 100. In the same counties, stores of less than supermarket size experienced *a drop of 33 cents in their per capita sales*. This coefficient could have had this particular value by chance about 90 times out of 100. However, the fact that the coefficient was negative and lower indicates that in these counties supermarkets probably gained relatively more from participant patronage than did the smaller stores (Table 4).

In counties where stores with less than $500,000 of annual sales dominated, the gain of 1 percent in the proportion of food stamp participants in total population resulted in a decline of $6.70 in per capita supermarket sales. This coefficient could have occurred by chance about 41 times out of 100. The smaller sized stores experienced a gain of $3.94 in their per capita sales. Again, the regression coefficient was not statistically significant; it could have occurred by chance almost 92 times out of 100. Nevertheless, the important point is that the coefficients in the second set of comparisons reflect associations opposite of those in the first set of regressions. In the second set *the smaller stores gained more in per capita sales than did the supermarkets*. Thus, since the market structure of the county appeared to have affected the patronage patterns of program participants, the food stamp program was probably neutral in its impact upon participant patronage patterns.

Location of each participant's residence, each county's dominant market structure with respect to kind and size of store, and each store's willingness to become certified to receive stamps combined to form the dominating force in store selection by program participants.

Tax receipts

Table 5 reports the total tax receipts from sales in retail food stores, receipts from purchases made with food stamps, and the tax receipts from food stamps associated with stamp bonuses. Tax receipts from purchases made with food stamps rose from $494,952 in 1966 to $1,729,488 in 1970. By 1970 tax receipts from stamp purchases accounted for almost 1 percent of total food store sales tax returns. Amounts of tax coming from the stamp bonuses represented the net tax gain,[6]

[6] While the stamp program constrains the substitution of non-food for foods, some substitution occurs. Thus, to the extent that substitution occurs there is a downward movement in tax receipts from food store sales. However, since

Table 5. Comparison of total sales tax receipts collected from retail food stores, participating counties, and tax receipts from purchases made with food stamps 1966–1970

Year	Sales tax from retail food stores of participating counties	Sales tax receipts derived from food stamp purchases	Sales tax receipts derived from bonus stamp purchases	Sales tax receipts derived from food stamp purchases as a percent of total sales tax receipts of food stores	Sales tax receipts derived from bonus stamp purchases as a percent of total sales tax receipts of food stores
1966	85,449,698	494,952	149,574	0.006	0.0019
1967	110,055,884	577,407	161,668	0.005	0.0015
1968	118,161,712	773,471	214,789	0.007	0.0018
1969	161,558,910	968,979	310,266	0.006	0.0019
1970	197,334,994	1,729,488	692,021	0.009	0.0035

since most if not all of the taxes received from *the stamps purchased in order to participate* in the program would have yielded the same amount in any case. By 1970 the tax receipts from *bonus stamps* were 40 percent of the total tax receipts derived from *total expenditures made with food stamps.*

Summary and Conclusions

The Michigan Food Stamp Program grew substantially between fiscal 1966 and 1970. It is still growing. Counties with a history of participation in direct commodity distribution, at least in the initial years of the food stamp program, contributed more participants to the program than did counties without such a history.

While many sources contributed participants, unemployment, the Michigan public assistance payments programs, and interstate migrant workers clearly were of major importance. Strikes appeared important but their association was blurred because they caused secondary unemployment in related firms not on strike. However, it appeared that as the number of strikers increased, the number of participants in the food stamp program likewise increased, although not on a 1:1 basis. It also seemed likely that as strikers returned to their jobs after a strike, the number who would cease their participation in the food stamp program would increase, but again, not necessarily on a 1:1 basis. Counties in the categories of lowest disposable income had more than a proportionate share of participants.

The food stamp program was neutral in its effect on the participants' choices of food stores. The market structure of each county, location of each participant's residence, and the willingness of merchants within a county to become certified to receive stamps appeared to be the primary factors influencing where participants spent their stamps. Counties with the stamp program reported substantial tax receipts from purchases made with bonus stamps.

In its performance, the Michigan Food Stamp Program reached several major groups including the unemployed, low income persons like migrant workers, and to a lesser extent, the blind, the aged, and the handicapped. It appears to be reaching the persons it was created to reach.

Bonus stamp expenditures helped support both the per capita sales made through retail food stores and the sales tax receipts reported for participating counties. The program's impact on the quality of participants' diets was not studied. As an interim approach it appears to have made a positive contribution to people and the retail food trade of Michigan. However, the major engagements remain—the fight against unemployment and inflation.

the substituted items likewise are taxed, the substitution of non-food purchases also raises taxes. To the extent that total purchases increase, total taxes likewise increase.

References

[1] HILDRETH, CLIFFORD, "Combining Cross Section Data and Time Series Data," unpublished Cowles Commission Discussion Paper 347, May 15, 1950.
[2] HOCH, IRVING, "Estimation of Production Function Parameters Combining Time-Series and Cross-Section Data," *Econometrica* 30:34–53, Jan. 1962.
[3] LOVE, HAROLD G., "The Reasons Participants Drop Out of the Food Stamp Program: A Case Study and Its Implications," *Am. J. Agr. Econ.* 52:387–394, Aug. 1970.
[4] PETERSON, RICHARD, unpublished staff study, Statistical Report Section, Michigan Department of Social Service, June 1971.
[5] SPARKS, W. R., *Estimates of the Demand for Food from Consumer Panel Data*, unpublished Ph.D. thesis, Michigan State University, 1961.
[6] WILKS, SAMUEL S., *Mathematical Statistics*, Princeton, Princeton University Press, 1943.

Appendix A

Suppose the true model for the relationship between the number of food stamp participants (Y) and unemployment was

$$Y = \alpha_1 U_n + \alpha_2 U_s + \alpha_3 S$$

where

U_n = number of unemployed not associated with strikes,

U_s = number of workers unemployed because their firms could not sell to or buy from (or both) striking firms,

S = number of workers on strike.

Here I reiterate that U_n and U_s CANNOT be observed independently (separately). In any case, total unemployment U is $U = U_n + U_s$, or more conveniently for later use, $U_n = U - U_s$.

Suppose that in addition $U_s=\gamma S$. This seems a realistic assumption for the short run (9 months or less). Most strikes are of relatively short duration and once the struck plants and the plants dependent on them are closed, the ratio of workers of the dependent plants to the workers of the struck plants will remain constant.

Given these assumptions and our original equation,

$$Y = \alpha_1 U_n + \alpha_2 U_s + \alpha_3 S,$$

we obtain

$$\begin{aligned} Y &= \alpha_1 U_n + \alpha_2 U_s + \alpha_3 S \\ &= \alpha_1 U + (\alpha_2 - \alpha_1) U_s + \alpha_3 S \\ &= \alpha_1 U + (\alpha_2 - \alpha_1)\gamma S + \alpha_3 S \\ &= \alpha_1 U + [(\alpha_2 - \alpha_1)\gamma + \alpha_3] S. \end{aligned}$$

Next estimate

$$Y = B_1 U + B_2 S,$$

then,

B_1 is an estimate of α_1 and B_2 is an estimate of $[(\alpha_2-\alpha_1)\gamma+\alpha_3]$.

If a combination of assumed values is substituted, we find

$$\begin{aligned} \alpha_1 &= 0.8 \\ \alpha_2 &= 0.4 \\ \gamma &= 2.0 \\ \alpha_3 &= 0.2 \end{aligned}$$

then B_2 equals -0.6 which corresponds with the observed coefficient.

Asset Replacement Principles*

R. K. Perrin

Using a general model of asset replacement, a replacement principle is derived which applies to both appreciating assets such as forests and depreciating assets such as equipment. The resulting replacement criterion provides a definition of opportunity costs appropriate for the replacement decision. The theory is presented graphically for the continuous time case, and two discrete-time examples are considered. Theoretical implications of changing discount rates and market forces are considered as they affect replacement policies.

This article will attempt to provide a more complete understanding of principles of asset replacement under certainty. The basic marginal principle, clearly enough, is to compare gains from keeping the current asset for another time interval with the *opportunity* gains which could be realized from a replacement asset during the same period.

Thus, a forest should be left to grow another year if the additional net returns are greater than the "average" annual returns from a new stand. A machine should be kept another period if the marginal costs of retaining it for another period are less than the "average" periodic costs of a replacement machine.

The problem of defining an appropriate concept of "average" opportunity gains associated with the replacement asset has been the source of much confusion and misunderstanding. The concept is difficult because it involves annualization of a lumpy stream of gains that is dependent upon the replacement policy for the replacement asset.

The problem of defining average opportunity returns has been satisfactorily resolved (for models of various degrees of generality) by Burt [1, 2], Bentley and Teeguarden [3], Dillon [5, Chap. 3], Gaffney [7, 8], Hirshleifer [9, Chap. 3], Jorgenson, *et al.* [10], Preinreich [12], and Winder and Trant [15]. In this article the resulting replacement principles will be derived in a sufficiently general manner to apply to assets which range from goods in process (such as a cask of wine or a forest), to capital equipment (machines, buildings, etc.), and to such unusual capital assets as dairy cows and orchards. For adaptation of the principles to assets with stochastic inputs, outputs, and life, the reader is referred to Burt [2] or Jorgenson, *et al.* [10]. (Terborgh [13] and Gaffney [8] adapt the principles to consider obsolescence, and Dillon [5] discusses the case of variable input levels.)

A Continuous-Time Replacement Model

The replacement problem is represented here in terms of continuous-time variables, not because most real world problems are of this type (they are not), but because it allows simpler algebraic and graphical analysis. The resulting replacement principles are adaptable to the discrete-time case, as will be shown.

The simplest assumption to make about the motivation of the asset manager is that he wishes to maximize the present value of the entire future stream of residual earnings from the productive process associated with the asset. The replacement problem is to choose a replacement age which maximizes this present value. (As Chisholm [4] notes, this is a deceptively simple criterion.) The relative value of future earnings versus present earnings is reflected by a discount rate (r) which is determined by either the cost of capital, the return on alternative investments, or preferences in the timing of personal consumption. More on this will be discussed later, but for the present the rate r can be taken as given.

The term "Defender" will be used for an asset already in use and the term "Challenger" for an asset which can be purchased to replace a Defender. The following notation will be used to describe the replacement problem:

$\rho = \ln(1+r)$ = the interest rate which, when compounded continuously, results in an annual growth rate of r, i.e., $e^{\rho t} = (1+r)^t$

t = an integer number of years

$M(a)$ = the market (or salvage) value of the asset at age a

$R(a)$ = the flow of residual earnings (current revenues less current

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R. K. Perrin *is assistant professor of economics at North Carolina State University, Raleigh.*

costs) from the process when the asset age is a

$C(b, s, m)$ = the present value of the stream of residual earnings from a Challenger to be purchased at age b and replaced at age s by a series of m identical Challengers

$D(a, c, m)$ = the present value of the stream of residual earnings from a Defender of age a to be replaced at age c by a series of m replacements.

Self-replacement

Assume initially there is no Defender in use and the Challenger, if acquired, will be replaced by a series of identical Challengers (self-replacement). The present value of the stream of earnings associated with the first asset alone is

$$C(b, s, 1) = \int_b^s R(t)e^{-\rho(t-b)}dt + M(s)e^{-\rho(s-b)} - M(b). \tag{1}$$

To determine the replacement age which maximizes the present value of the returns from just this first asset, the derivative of $C(b, s, 1)$ with respect to replacement age s is set equal to zero to obtain[1]

$$R(s) + M'(s) = \rho M(s), \tag{2}$$

where the prime indicates derivative. It is apparent from this result that acquisition age, b, is irrelevant to the replacement problem in this form, and that the value-maximizing replacement age s is the age at which marginal revenue (residual earnings plus changes in asset value) equals marginal opportunity costs (defined here as the interest which could be earned by selling the asset). Figure 1 shows a possible path of $R(s)+M'(s)$ through time and the replacement age s_1 which satisfies condition (2).

The basic assumption, however, was that the asset manager wished to maximize the present value of the entire stream of earnings, $C(b, s, \infty)$, rather than just the stream associated with the first asset. To simplify the notation (but without loss of generality) one can assume that the assets will be acquired at age zero. Then the present value of the entire stream is

[1] The differentiation of the first term in (1) follows directly from the fundamental theorem of calculus, i.e., given $F(x)=\int_a^x f(u)du$, the derivative of $F(x)$ at x is equal to $f(x)$.

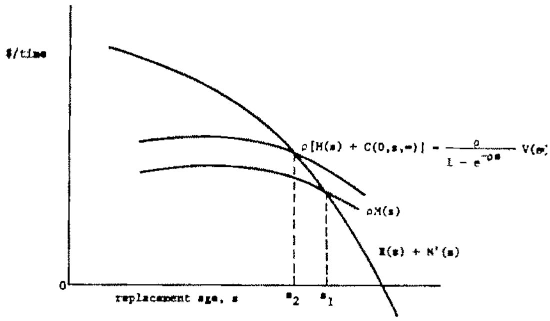

Figure 1. The self-replacement solution

$$\begin{aligned} C(0, s, \infty) &= C(0, s, 1) + e^{-\rho s}C(0, s, 1) \\ &\quad + e^{-\rho 2s}C(0, s, 1) + \cdots \\ &= C(0, s, 1)\{1 + e^{-\rho s} + e^{-\rho 2s} + \cdots\} \end{aligned}$$

or

$$C(0, s, \infty) = \frac{1}{1 - e^{-\rho s}} C(0, s, 1), \tag{3}$$

which is just the expression for the present value of a perpetual annuity of amount $C(0, s, 1)$ received every s years.[2] To maximize this value with respect to replacement age s, its derivative is found

$$\frac{\partial}{\partial s}C(0, s, \infty) = -\frac{\rho e^{-\rho s}}{(1 - e^{-\rho s})^2}C(0, s, 1) + \frac{e^{-\rho s}}{1 - e^{-\rho s}}[R(s) + M'(s) - \rho M(s)].$$

Setting this equal to zero yields

$$\begin{aligned} R(s) + M'(s) &= \rho\left(M(s) + \frac{C(0, s, 1)}{1 - e^{-\rho s}}\right) \\ &= \rho(M(s) + C(0, s, \infty)) \end{aligned} \tag{4}$$

The difference between this criterion and (2) reflects the opportunity cost of postponing the earnings which will be realized from the next and subsequent assets. The greater these future

[2] To obtain result (3), one must evaluate the series $S_k = (1+e^{-\rho s}+e^{-\rho 2s}+ \cdots +e^{-\rho ks})$ as k goes to infinity. One way to evaluate this is to note that $S_k e^{-\rho s} = (e^{-\rho s}+e^{-\rho 2s}+e^{-\rho 3s}+ \cdots +e^{-\rho(k+1)s})$ and that, therefore, $S_k - S_k e^{-\rho s} = (1-e^{-\rho(k+1)s})$. Thus, S_k can be rewritten as $S_k=(1-e^{-\rho s})^{-1}(1-e^{-\rho(K+1)s})$, and its limit as k goes to infinity is clearly $(1-e^{-\rho s})^{-1}$. The annually-compounded analog of this expression is $(1-(1+r)^{-s})^{-1}$, which is known as the value of a perpetual annuity of \$1, received every s years beginning now.

earnings, the more impatient the firm will be to replace the current asset. Alternatives on the right-hand side of (4) represent a concept of "average" opportunity returns appropriate for replacement decisions. To maximize present value, the asset should be replaced when the net flow of benefits equals the flow which could be realized by immediate replacement. Substituting from equation (1) and collecting terms,

$$R(s) + M'(s) = \frac{\rho}{1 - e^{-\rho s}}\left[\int_0^s R(t)e^{-\rho t}dt + M(s)e^{-\rho s} - M(o) + M(s)(1 - e^{-\rho s})\right]$$

or

$$R(s) + M'(s) = \frac{\rho}{1 - e^{-\rho s}} \cdot \left[\int_0^s R(t)e^{-\rho t}dt + M(s) - M(o)\right]. \tag{4.1}$$

Equation (4.1) is the general principle of replacement derived by Gaffney [7, p. 70] and others. The principle can be interpreted more easily if it is rewritten as

$$R(s) + M'(s) = \frac{\rho}{1 - e^{-\rho s}} V(s) \tag{4.2}$$

where

$$V(s) = \int_0^s R(t)e^{-\rho t}dt + M(s) - M(o).$$

$V(s)$ can be interpreted as the present value of an upcoming replacement cycle ***at the moment of replacement***, for at that moment the value $M(s) - M(o)$ is realized (or lost) on the exchange of the old for the new asset, and the integral yields the present value of earnings from the new asset until the time it is replaced. In effect, once the series of replacement cycles is initiated, the amount $V(s)$ is received as a perpetual annuity every s years. The ***capital recovery factor***, $\rho/(1-e^{-\rho s})$, converts this annuity into an equivalent constant flow of earnings.[3] The replacement principle (4.2) specifies the asset be held to the age in which marginal revenues equal marginal opportunity costs, with the latter being interpreted this time as the flow of earnings which would be realized from an s-year replacement policy. This criterion is shown in Figure 1 to yield an optimum replacement age s_2. Thus, consideration of earnings from the second and subsequent assets leads to an earlier replacement age than the one-cycle solution s_1. For ages younger than s_2, the flow of current earnings is higher than the equivalent flow which would be earned by consistent replacement at age s_2. For older ages, the flow of current earnings is less than that which could be obtained from an s_2-year replacement policy.

As a special case of the general replacement principle, consider an asset for which $R(a)$ is constant through time, which has often been assumed for the wine-aging and forest-harvest problems. Then the marginal condition of (4.1) becomes

$$R + M'(s) = \frac{\rho}{1 - e^{-\rho s}}\left[R\int_0^s e^{-\rho t}dt + M(s) - M(o)\right] = \frac{\rho}{1 - e^{-\rho s}}\left[R\left(\frac{1 - e^{-\rho s}}{\rho}\right) + M(s) - M(o)\right]$$

or

$$\frac{M'(s)}{M(s) - M(o)} = \frac{\rho}{1 - e^{-\rho s}}. \tag{5}$$

Thus, if the flow of current earnings is constant, the level of the flow is irrelevant to the replacement decision. The optimum replacement age occurs when the rate of growth in net market value equals the capital recovery factor. This marginal criterion, equation (5), is equivalent to the Faustmann criterion for determining the optimum harvest age for a forest [3, 5, 7, 8]. This equivalency is not surprising, since the approach of the Faustmann model is to impute the residual earnings to the land and to maximize the resulting "soil rent," whereas the model here maximizes unimputed residual earnings.

Replacement with technologically improved assets

Often the Challenger will be an improved asset compared to the Defender. The present value of the Defender and the series of Challengers which will replace it is

$$D(a, c, \infty) = D(a, c, 1) + C(0, s, \infty)e^{-\rho(c-a)}.$$

[3] The denominator yields the present value of the annuity, as discussed earlier, while the ρ in the numerator converts this present value into a continuous flow.

Differentiating with respect to replacement age c, the maximizing condition is obtained

$$(6) \quad R(c) + M'(c) = \rho[M(c) + C(0, s, \infty)]$$

In this case, the Defender should be kept until the marginal revenues equal the revenues which could be obtained as interest on the sale value of the Defender plus the capitalized value of the series of Challengers. Thus, the higher the capitalized value of the improved Challengers, the sooner the Defender will be replaced. As a practical matter, a decision maker might compute $C(0, s, \infty)$ each year using the best data available on the Challenger and compare net returns expected next year from the old asset with $\rho[M(c)+C(0, s, \infty)]$. If net returns from the old asset are larger, he will continue with it for another year at which time an updated comparison is made, and so on, making a decision each year with the best information available at the time.

Effect of the discount rate on replacement age

It has often been assumed that higher discount rates will result in an earlier optimum replacement age. Though this has been well demonstrated for the wine-aging problem, the following analysis will show that it is not true as a general conclusion.

First, consider the replacement rule (4.1) under a zero discount rate. From L'Hospital's rule,

$$\lim_{\rho \to 0} \frac{\rho}{1 - e^{-\rho s}} = \frac{1}{s},$$

so that equation (4.1) with a zero discount rate becomes

$$(7) \quad R(s) + M'(s) = \frac{1}{s}\left[\int_0^s R(t)dt + M(s) - M(o)\right],$$

i.e., the optimum replacement age is that age s at which the marginal revenue equals the average undiscounted revenue over time. The top portion of Figure 2 shows for a particular asset the cumulative undiscounted revenue over time. The zero discount rate solutions is s_1, which is also the age which maximizes average undiscounted revenue over time, as pointed out by Faris [6].

Figure 2 also shows the optimum replacement age s_2 for a positive discount rate ρ and the replacement age younger than s_1. The question is whether the non-zero discount rate

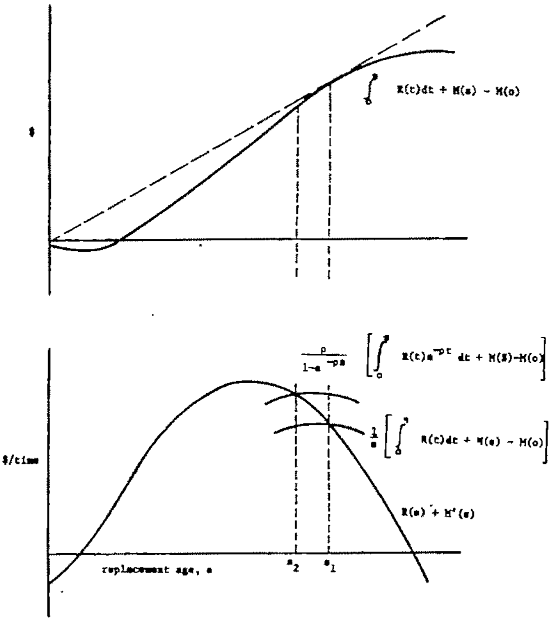

Figure 2. The effect of discount rate on replacement age

curve in the lower part of Figure 2 lies above or below the zero discount curve, or whether they cross somewhere. In other words, is the derivative of the right-hand side of (4.2),

$$\frac{d}{d\rho}\left[\frac{\rho}{1 - e^{-\rho s}} V(a)\right] = V(a)\frac{\partial}{\partial\rho}\left[\frac{\rho}{1 - e^{-\rho s}}\right] + \frac{\rho}{1 - e^{-\rho s}}\frac{\partial}{\partial\rho}V(a),$$

positive or negative? Since the first term is positive while the second is negative, the sign of the derivative may be either positive *or* negative, depending on the value of ρ, $M(a)$, $M(o)$, and the path of $R(a)$ up to age s. Some assets may be replaced earlier with rising discount rates while others may be replaced later; and in fact, a given asset may be replaced later up to a given rate but earlier thereafter (that is, the two criterion curves in the lower part of Figure 2 may cross).

In the case of a forest harvest or wine-aging problem, however, the replacement rule reduces to (5), and it is clear that as the discount rate rises, the capital recovery factor rises, resulting in an unambiguously earlier replacement age.

Residual Earnings vs. Market Equilibrium

The preceding discussion, analyzing how firms should act to maximize residual earnings,

is strongly firm-oriented. It is also important to consider the implications of market forces which would be generated by the existence of any such residual earnings (over and above normal returns). If such residuals exist for one firm, it can be expected that other firms will be interested in appropriating some of the residual earnings for themselves, with the result that input prices will be bid up, output prices will fall with expanded production, or perhaps both. In the case of timber, for example, the existence of residual earnings would lead to higher rents earned by timber land if such land were in fixed supply, or would ultimately force the price of lumber down due to expanded production if timber land were unlimited. Either way, the residual earnings will be eliminated. If some trucking activity yields residual earnings, quasi-rents can also be expected to be capitalized into the price of trucks if their supply were fixed, or competition might lower rates until residual earnings disappeared, or again there might be a rise in the value of trucking permits. The point is that in equilibrium the present value of the stream of residual earnings from an investment will indeed be at a maximum with respect to replacement age, but this maximum will be zero.

In terms of the previous discussion, suppose that the present value of residual earnings from a single production cycle, $C(0, s, 1)$, is temporarily positive, and the firm plans a replacement age s_2 according to (4) and Figure 1. The firm then enjoys a rent of amount $\rho C(0, s, 1)/(1-e^{-\rho s})$ since current returns exceed the market rate of return by this amount. As other firms become aware of the existence of this rent, they will tend to bid up the market prices (either nominal rental rates or sale values) of one or more of the resources involved. The rise in prices will continue until the rent is exhausted.

What will be the effect on optimum asset replacement age? This depends upon the elasticity of supply of assets of various ages. If the supply of assets of all ages were perfectly elastic, $M(a)$ would not be affected so that capitalization of the residual stream would affect only $R(a)$. In this case both sides of (4) would fall by the amount of the rent previously earned, leaving the optimum replacement age unaffected. If the supplies of assets of various ages were not perfectly elastic, the bidding process would increase their average market value and possibly alter their relative values. In equilibrium the market value of an asset of any age will then equal the discounted value of remaining net earnings. If this is the case, the market values will have adjusted so that current returns, $R(a)$, equal interest on the market value of the asset plus depreciation, $\rho M(a) + M'(a)$.[4] Thus, the replacement criterion (4) will be met for an asset of any age and firms will be indifferent regarding replacement as long as the asset generates any net earnings.

From Continuous to Discrete World

In most real replacement problems, net revenues and market values are observed as discrete annual levels rather than continuous functions of time. In this case, the present value of future earnings is determined by

$$C(0, s, \infty) = \frac{1}{1-(1+r)^{-s}}\left[\sum_{t=1}^{s}(1+r)^{-t}R(t) + (1+r)^{-s}M(s) - M(o)\right] \tag{8}$$

or

$$C(0, s, \infty) = \frac{1}{1-(1+r)^{-s}}V(s) - M(s) \tag{8.1}$$

rather than by equation (3). The most direct discrete-time analog of the replacement rule (4.1) is

$$R(s+1) + \Delta M(s+1) = \frac{r}{1-(1+r)^{-s}} \cdot \left[\sum_{t=1}^{s}(1+r)^{-t}R(t) + M(s) - M(o)\right] \tag{9}$$

or

$$R(s+1) + \Delta M(s+1) = \frac{r}{1-(1+r)^{-s}}V(s) \tag{9.1}$$

where $\Delta M(a)$ is the change in market value during the ath year of life. (The capital recovery factor in this case is a value commonly tabulated in annuity tables as the amount of an annuity whose present value is one.) $R(s+1) + \Delta M(s+1)$ is more logical than $R(s)+\Delta M(s)$ since the returns in the forthcoming year should be compared with the returns equivalent to those from replacing at the current age.

[4] Yotopoulos [16] seized upon this fact to infer the flow services from capital goods given only information on their market price by age.

Use of a marginal criterion such as (9.1) for optimizing in a discrete world presents certain problems. In the first place, the criterion is not likely to be met exactly for an integer number of years, and selection of the year in which the criterion is most nearly satisfied will not always lead to the value-maximizing solution. Second, there is some question as to whether the continuous-time capital recovery factor, $\rho/(1-e^{-\rho s})$, or the discrete-time factor will lead to the correct solution more frequently.[5] Burt [2] resolved these issues by deriving a pair of marginal conditions which insure that the optimum age is chosen but computational requirements increase accordingly.[6]

From a computational viewpoint, however, it is apparent from (8.1) and (9.1) that it is about as easy to evaluate the present value itself as to evaluate the marginal criterion. Given that the marginal criterion may result in a one-year error, calculation of present values via (8.1) will often be a better search procedure.

The Choice of Discount Rate

As previously mentioned, the appropriate discount rate may be determined by the cost of capital, the return on alternative investment possibilities, or the timing of personal consumption. None of these choices is universally appropriate. If the owner faces a perfect capital market, then the cost of capital is appropriate since it represents the rate at which he has the opportunity to trade present for future dollars. On the other hand, it is easy to envision a "destitute" owner who values future earnings quite low relative to present earnings, that is, one who has a high personal discount rate. If there is no capital market in which this person can borrow at a lower rate, then his personal time preference rate would be appropriate in determining a replacement age. As a third alternative, it may be argued that the internal rate of return on the asset is the appropriate discount rate. (To find this internal rate of return, one must calculate the present value $C(0, s, \infty)$ under an optimal replacement policy for each of several discount rates until a rate is found such that $C(0, s, \infty)=0$.) This is appropriate if capital is fixed and there are no accessible external capital markets, if the asset in question has a higher internal rate of return than any alternative asset, and if *all* the returns from the asset can be reinvested at the same rate of return. It is important to note, however, that the internal rate of return is a function of the price of inputs required in the productive process, including the asset price. If the internal rate of return is above the market rate for ventures of similar risk, then market forces can be expected to drive up the asset price (or that of some associated limiting factor of production) until the rate of return falls to the market rate, whether or not a particular owner has access to a capital market. The market rate of return for ventures of similar riskiness is then the appropriate discount rate if equilibrium prices of all inputs are expected to prevail by the first replacement date.

Table 1. Parameters of a hardwood forest harvest problem[a]

Age a	Net stumpage value at age a $M(a)$	Growth rate $M'(a+1)/M(a)$	Capital recovery factor[b] $r/(1-(1+r)^{-a}$: $r=0.05$	$r=0.10$
	(1)	(2)	(3)	(4)
14	0	—	0.101	0.136
15	15.70	0.410	0.096	0.131
16	22.14	0.305	0.092	0.128
17	28.89	0.242	0.089	0.125
18	35.88	0.199	0.086	0.122
19	43.03	0.169	0.083	0.120
20	50.30	0.146	0.080	0.117
21	57.65	0.128	0.078	0.116
22	65.05	0.114	0.076	0.114
23	72.48	0.102	0.074	0.113
24	79.91	0.092	0.072	0.111
25	87.33	0.084	0.071	0.110
26	94.71	0.077	0.070	0.109
27	102.05	0.071	0.068	0.108
28	109.33	0.065	0.067	0.107
29	116.54	0.061	0.066	0.107
30	123.68	0.056	0.065	0.106

[a] The value of pulp, net of harvest costs, from unmanaged hardwood stands on wet flat forest sites in the southeast. Taken from Table 2 of Porterfield [11].

[b] The amount of an annuity whose present value is 1.00.

Two Examples

Table 1 presents the parameters of a forest harvest problem, in which column 1 shows the

[5] Direct differentiation of equation (7) yields an optimum condition equivalent to (8) but with ρ rather than r in the numerator. The continuous-time capital recovery factor is smaller than the discrete factor by the fraction ρ/r. Thus, it would lead to selection of an older replacement age in some cases.

[6] In terms of the variables defined here, Burt begins with the inequalities $C(O, s-1, \infty)\leq C(O, s, \infty)\geq C(O, s+1, \infty)$ and by substitution derives the inequalities

$$R(s+1)+\Delta M(s+1)\leq \frac{r}{1-(1+r)^{-s}}V(s) \leq R(s)+(1+r)\Delta M(s)$$

as marginal replacement criteria.

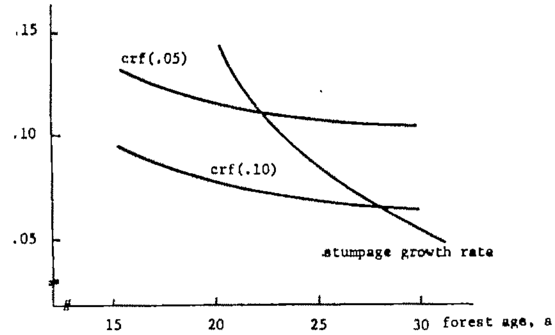

Figure 3. The tree harvest problem

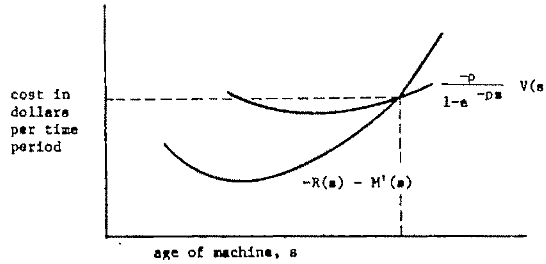

Figure 4. The self-replacement solution for a machine

value of pulpwood, net of harvesting costs, if the crop is harvested at age a. Since the data refer to unmanaged hardwood stands, regeneration costs, $M(o)$, and annual revenues (costs, in this case), $R(a)$, are zero. If the forest is to be replaced by an identical forest, equation (5) provides the approximate marginal harvest (replacement) criterion. When the rate of growth in stumpage value most nearly equals the capital recovery factor, it is time to harvest. For an interest rate of 5 percent, this occurs at age 28, and the present value of future earnings is maximized at \$37.17. For an interest rate of 10 percent, the optimum age is reduced to 22 years. In the latter case, the maximum present value of future harvests drops to \$9.11. The graphic solution is sketched in Figure 3. Of course, if the hardwood forest were being challenged by some other species with a higher present value, then equation (6) would be appropriate and would result in an earlier optimum harvest age.

The replacement of durable equipment is a special case of the replacement theory developed here, but it is one which has received a great deal of attention in the literature. In considering such an asset, current costs can be defined to include any deterioration in the flow of services with age. By this device the total value of the services rendered by the machine is irrelevant to the replacement decision since the flow of services is by definition constant. Maximizing the present value of residual earnings is then equivalent to minimizing the present value of the costs of the machine. Figure 4 shows a typical path for repair, depreciation, and deterioration $(-R(s)-M'(s))$ as a machine ages, along with the criterion curve defining the appropriate "average" opportunity costs against which these costs must be compared.[7] (Figure 4 is merely Figure 1 upside down, since costs are negative returns.)

Table 2 shows in column 1 the resale value of a \$3,000 truck as it ages, assuming an annual use of 20,000 miles. Column 2 shows the expected annual repair costs during the ath year of life, while column 3 lists repairs plus depreciation—total marginal costs (shown as

[7] Terborgh [13] refers to this average opportunity cost as the "adverse minimum."

Table 2. Parameters of a truck replacement problem[a]

Age a	Year-end value $M(a)$	Annual repairs $R(a)$	Annual costs $R(a)+M'(a)$	$V(a)$	Capital[b] recovery factor $r=0.10$	$\text{crf}\cdot V(a)$	Present value $C(0, a, \infty)$
	(1)	(2)	(3)	(4)	(5)	(6)	(7)
1	2307	−100	−793	− 784	1.099	−862	
2	1773	−200	−734	−1484	0.576	−855	
3	1362	−320	−731	−2135	0.402	−858	
4	1047	−420	−735	−2736	0.315	−862	
5	804	−520	−763	−3302	0.264	−872	−9524
6	618	−640	−826	−3849	0.230	−884	−9455
7	474	−720	−864	−4372	0.205	−896	9434
8	366	−820	−928	−4862	0.187	−909	−9458

[a] Data are for \$3,000 trucks with statistically estimated depreciation and repair costs, taken from Toro-Viscarrondo [14].
[b] The amount of an annuity whose present value is 1.00.

negative returns) for each year. Column 4 shows $V(a)$, the total repair costs discounted to age a plus trade-in outlay at age a. The approximate criterion (9.1) requires that the product $crf \cdot V(a)$ (column 6) be equal to the total marginal costs for year $(a+1)$. This criterion is most nearly met by replacement at age 6.

It is useful in understanding this problem to recall the significance of the value $crf \cdot V$. Once the series of replacement cycles is initiated, that is, once such a truck is bought, the amount $crf \cdot V(a)$ is the annualized cost which would be incurred by replacing this truck and all future trucks when they reach age a. It can be quickly noted that in this problem the annualized cost reaches a minimum at age 2 ($855 per year), but minimizing this type of annualized cost *is not an appropriate goal.* The owner has the alternative of keeping the present truck one more year at a much lower cost of only $731. Moving down to age 6, it is again apparent the best decision is to keep the truck to age 7 at a cost of $864, rather than to incur annualized costs of $884 by an age 6 replacement policy. At age 7 it becomes cheaper to replace ($896 per year) than to keep for another year ($928). The present value of costs for a seven-year replacement policy, calculated according to equation (8.1), is the smallest possible at $9,434. In this case the use of the approximate marginal criterion (9.1) led to the selection of a non-optimal six-year replacement policy, though the cost of the wrong decision in this case is slight (only $21 in present value). While this truck replacement problem demonstrates the logic of the marginal replacement criterion, it also demonstrates the previous conclusions that the approximate marginal criterion can lead to a one-year error and that direct calculation of present values can be a better search procedure for discrete-time problems.

References

[1] BURT, OSCAR R., "Economic Replacement," *SIAM Rev.* 5:203–208, July 1963.

[2] ———, "Optimal Replacement Under Risk," *J. Farm Econ.* 47:324–346, May 1965.

[3] BENTLEY, WILLIAM, R., AND DENNIS E. TEEGUARDEN, "Financial Maturity: A Theoretical Review," *Forest Sci.* 11:76–87, March 1965.

[4] CHISHOLM, ANTHONY H., "Criteria for Determining the Optimum Replacement Pattern," *J. Farm Econ.* 48:107–112, Feb. 1966.

[5] DILLON, JOHN L., *The Analysis of Response in Crop & Livestock Production*, New York, Pergamon Press, 1968.

[6] FARIS, J. EDWIN, "Analytical Techniques Used in Determining the Optimum Replacement Pattern," *J. Farm Econ.* 42:755–766, Nov. 1960.

[7] GAFFNEY, M. MASON, "Concepts of Financial Maturity of Timber and Other Assets," A.E. Information Series No. 62, Department of Agricultural Economics, North Carolina State University, Raleigh, Sept. 1957.

[8] ———, "Replacement of Individual by Mass Systems in Urban Growth," presented before the American Real Estate and Urban Economics Association, New York, Dec. 1969.

[9] HIRSHLEIFER, JACK, *Investment, Interest and Capital*, Englewood Cliffs, N.J., Prentice-Hall, Inc., 1970.

[10] JORGENSON, D. W., J. J. MCCALL, AND R. RADNER, *Optimal Replacement Policy*, Chicago, Rand McNally & Company, 1967.

[11] PORTERFIELD, RICHARD L., "Financial Maturity of Certain Southern Mixed Hardwood Stands," unpublished M.S. thesis, North Carolina State University, 1970.

[12] PREINREICH, GABRIEL A. D., "The Economic Life of Industrial Equipment," *Econometrica* 8:12–44, Jan. 1940.

[13] TERBORGH, GEORGE, *Dynamic Equipment Policy*, New York, McGraw-Hill Book Co., Inc., 1949.

[14] TORO-VISCARRONDO, CARLOS, "Economic Replacement: A Case Study," unpublished M.S. thesis, North Carolina State University, 1964.

[15] WINDER, J. W. L., AND G. I. TRANT, "Comments on 'Determining the Optimum Replacement Pattern,' " *J. Farm Econ.* 43:939–951, Nov. 1961.

[16] YOTOPOULOS, PAN A., "From Stock to Flow Capital Inputs for Agricultural Production Functions: A Microanalytic Approach," *J. Farm Econ.* 49:476–491, May 1967.

Evaluation of Alternative Flexibility Restraint Procedures For Recursive Programming Models Used for Prediction*

THOMAS A. MILLER

Recursive programming models for estimating production response may be generalized from the original "recursive" formulation to a formulation that simply attempts to limit the linear programming solution to a reasonable subset. This article outlines a framework for evaluating the effect of alternative flexibility restraint procedures on the accuracy of such recursive programming models. Statistical estimates are developed for the total expected error of predictions, given a specified set of population and model characteristics. The analysis suggests that recursive programming models achieve some measure of statistical accuracy.

AGRICULTURAL ECONOMISTS have long been in pursuit of an evasive goal, a technique or tool to provide accurate production response estimates or predictions for future time periods. The 1960's witnessed a new technique being examined, precisely defined, tested, and finally used in operational situations. This technique is *recursive programming* (RP). Its value rests in its ability to encompass the characteristics of both short-run regression estimates of future response under the assumed continuation of historical structural relationships and long-run linear programming estimates of future response based on the assumption that the actual response of farmers will tend toward the "optimum" or "most profitable" response in the long run.

The RP model was originally developed as a linear programming model that makes year-to-year sequential predictions of output over a period of years. This formulation assumes that farmers view next year's production plan as a deviation from the current farm organization with the linkage between the current and future plans achieved by the use of flexibility restraints. Day [2, 3], Schaller [8], and others [5, 7, 11] have developed and utilized such procedures, generally using flexibility restraints to limit the year-to-year change in production levels.

* The concepts presented here are an outgrowth of research by the Aggregate Production Analysis Team, Farm Production Economics Division, Economic Research Service, USDA, described by Jerry A. Sharples and W. Neill Schaller, [10]. Appreciation is extended to team members for their comments on earlier drafts of this manuscript.

THOMAS A. MILLER *is an agricultural economist with the Farm Production Economics Division, Economic Research Service, USDA, stationed at Colorado State University, Fort Collins.*

Restricting the linear programming solution to a specified "reasonable" subset has been a recent generalization in the formulation of RP models. This subset is not necessarily dependent on current production levels. Rather it is defined in terms of all available information that provides clues to the future production response. Thus constructed, the RP model may be considered one of restrained profit maximization. It represents the actions of farmers whose decisions, though based on the profit motive, are subject to various implicit and explicit resource allocation restraints.

The predictive accuracy of such models rests primarily on flexibility restraints. At the same time, there are many possible methods of estimating these restraints and the research worker is faced with the rather difficult and usually arbitrary decision of choosing the best method for each specific restraint. The purpose of this paper is to evaluate objectively several methods of determining flexibility restraints. The evaluation criterion is the total expected error of the final RP model predictions. Particular attention is given to the characteristics of the underlying population that influence the effectiveness of alternative flexibility restraints.

Procedures of Determining Flexibility Restraints

A range of procedures may be used for determining flexibility restraints, or more specifically, the upper and lower bounds. These bounds may restrict activities or groups of activities. The logic and purpose of flexibility restraints in the RP model were first discussed by Day [4, pp. 110–111],

> . . . These constraints specify that in any one year only a limited change from the preceding year's production can be expected. This hypothesis is based on the conglomerate of forces

which lead to caution by farmers in altering established production patterns. Primary among them are uncertainty of price and yield expectations and restriction on the aggregative supply of production inputs . . .

The flexibility constraints can be expressed in dynamic notation as follows:

$$X_1(t) \leq (1+\bar{\beta}_1)X_1(t-1)$$
$$X_2(t) \leq (1+\bar{\beta}_2)X_2(t-1)$$
$$-X_1(t) \leq -(1-\beta_1)X_1(t-1)$$
$$-X_2(t) \leq -(1-\beta_2)X_2(t-1)$$

. . . in which we shall call the β's *flexibility coefficients*.

The first equation . . . asserts that the acreage of the first crop will not exceed the previous year's acreage plus some proportion of its determined by the upper flexibility coefficient $\bar{\beta}_1$. Equation 3 . . . asserts that the acreage of the first crop must not be less than an amount determined by the lower flexibility coefficient, β, and the preceding year's acreage. Equations 2 and 4 . . . have the same meanings, respectively, for the second crop.

Schaller [9, pp. 6–25] discussed various procedures that may be useful for determining flexibility restraints. In summary form, these methods are:

(1) Informed judgment whereby people who are familiar with the situation estimate the maximum changes that may be expected.

(2) Flexibility coefficients estimated as averages (means) of positive and negative percentage changes in the past.

(3) Flexibility coefficients described by method (2) plus (minus) the standard deviation of the respective increasing (decreasing) percentages.

(4) Flexibility coefficients defined as the maximum of historical percent changes.

(5) Estimation of flexibility coefficients by the simple least squares model,

$$X_t' = bX_{t-1}.$$

(6) Estimation of flexibility coefficients by more general least squares models, in general

$$X_t' = a + bX_{t-1} + c_1Z_1 + \cdots + c_pZ_p.$$

(7) Least squares estimates of flexibility coefficients adjusted by standard errors. These standard errors may be either (a) the standard error of the regression coefficient b or (b) standard error of the estimate of X_t'.[1]

(8) Use of a single least squares equation to derive both bounds. In this case, a least squares point estimate plus and minus some function of the standard error serves as upper and lower bounds. This procedure defines the allowable range around a *forecast* of year t rather than around the *actual* $t-1$ value.

(9) Analysis of the discrepancy between the optimum and the actual response.

(10) Basing the flexibility restraints on their shadow prices.

Theoretical Framework

Consider the problem of using the RP model to estimate the total acres to be planted next year for a crop within a certain geographic area. Certain relationships within or assumptions about the underlying population are of critical importance in choosing the best method of determining flexibility restraints for a specific case. These relationships include (1) the significance of time trend or, alternatively, the lack of time trend in the historical series; (2) the presence or lack of serial correlation in the historical acreage series; (3) the importance of identifiable independent variables in influencing the acreage of the crop in question; (4) the statistical probability distribution of the disturbance term (random or unexplained variation); and (5) the proportion of time the RP model accurately predicts the *direction* of the change and reaches the upper or lower bound.

These relationships are important to the RP model in the same manner that such characteristics of the population are important in all statistical work; however, due to the wide range of techniques available for determining flexibility restraints, the existence of certain relationships may be even more important in RP models. For example, choice of the wrong flexibility restraint technique may lead to greater error in final predictions than using an inappropriate model in least squares regression.

A hypothetical population

It is useful to specify a set of such relationships for a hypothetical population as a basis for the detailed analysis of flexibility restraint procedures. Assume the population of historical acreage data may be expressed as

[1] The data were separated into increasing and decreasing years for methods 5, 6, and 7 involving least squares analyses. Thus b is an estimate of $(1+\bar{B})$ when increasing years are used and an estimate of $(1-B)$ when decreasing years are used.

(1) $Y_i = \mu + u_i \qquad i = 1, 2, \cdots, n$

where

$$E(u_i) = 0 \qquad \text{for all } i$$

(2) $$E(u_i u_{i+s}) = \begin{cases} 0 & \text{for } s \neq 0 \text{ for all } i \\ \sigma^2 & \text{for } s = 0 \text{ for all } i \end{cases}$$

(3) u_i has a normal distribution for all i

and for the RP model, assume that the optimum solution level of crop Y in the following year will be at the upper or lower bound

(4) $$Y_o = (\text{Upper bound}) \quad \text{or} \quad Y_o = (\text{Lower bound}).$$

These four assumptions may be summarized as a normally and independently distributed time series with no trend and a RP model with no physical restraints for the crop in question within the range of the upper and lower bounds.

Assumptions 1, 2, and 3 are encountered often in actual data series and constitute a suitable base for analysis of flexibility restraints; they may be modified later to include trend, independent variables, etc.[3] Assumption 4 provides a key point of departure for the theoretical framework that will be developed. As Schaller states [9, p. 8],

> It follows, incidentally, that there would be no great advantage to the programming model over conventional time series models if the flexibility restraints were always effective. We would define the upper bounds as acreage estimates for the more profitable crops and the lower bounds as our predictions for crops with relatively low returns. The extent to which the upper and lower bounds are effective will depend, of course, on the other restraints in the model. If the model includes a fairly detailed set of other restraints, the individual commodity estimates are not likely to be determined by their upper and lower bounds as often as when the model has few other restraints.

Unfortunately, RP models of producing regions may contain no physical resource restraints for many crops. The problem is compounded by the fact that profit relations among these crops often change on a year-to-year basis. In such cases, the best the optimization portion of the RP model can do is to predict accurately the direction of the change—the problem of predicting the magnitude of the change is left to the flexibility restraints. This RP model is the more general model of restrained profit maximization. The accuracy of the RP model within this framework can be examined after a few concepts relating to expected errors in predictions are developed.

Measures of error

The *mean square error* of a prediction provides a useful method of approach; it is defined as the expected value of the square of the difference between the prediction and the actual value that occurs. For example, if the current year's value, Y_n, is considered a prediction of Y_{n+1}, the mean square error is

$$D^2(Y_n) = E[Y_n - Y_{n+1}]^2.$$

From Equation (1),

$$\begin{aligned} D^2(Y_n) &= E[\mu + u_n - (\mu + u_{n+1})]^2 \\ &= E[u_n - u_{n+1}]^2 \\ &= E[u_n^2 - 2u_n u_{n+1} + u_{n+1}^2] \end{aligned}$$

which from Equation (2) gives

(5) $$D^2(Y_n) = 2\sigma^2.$$

The *expected error* of the prediction is defined as the root of the mean square error or $\sqrt{2}\,\sigma$ when the current year's value is used as the prediction of the following year.

As another example, if the mean of the historical series, $\bar{Y}$, is considered a prediction of Y_{n+1}, then the mean square error becomes

$$\begin{aligned} D^2(\bar{Y}) &= E[\bar{Y} - Y_{n+1}]^2 \\ &= E[\bar{Y} - (\mu + u_{n+1})]^2 \\ &= E[(\bar{Y} - \mu)^2 + 2(\bar{Y} - \mu)(u_{n+1}) + u_{n+1}^2]. \end{aligned}$$

From the theory of statistics, $E(\bar{Y}-\mu)^2 = \sigma^2/n$, the variance of the mean. Making this substitution and from Equation (2),

(6) $$D^2(\bar{Y}) = \sigma^2\left(1 + \frac{1}{n}\right).$$

Thus, the expected error of the mean as a prediction of the following year would be

[3] It may be argued that the hypothetical population excludes some situations where RP models have a potential advantage over least square techniques, mainly where structural changes such as new government programs or new technological developments make regression assumptions invalid. Nevertheless, the hypothetical population depicts a situation in which RP is often used. For example, Henderson [7], Schaller and Dean [8], and Zepp and McAlexander [11] are all making response estimates where no basic structural change has occurred.

$\sigma\sqrt{1+1/n}$, a value that approaches σ as the number of years used to compute the mean increases.

Total expected error of a simple recursive model

Given the hypothetical population expressed in Equations (1) through (4), it is possible to determine equivalent measures of error for a simple RP model. Consider a simplification of Schaller's eighth method of determining flexibility coefficients presented earlier, a least squares forecast of year $n+1$ (say, the mean) plus and minus some function of the standard error. Specifically, consider the flexibility restraints defined as

$$\text{(7)} \qquad (\text{Upper bound}) = \bar{Y}(1 + \hat{\beta})$$

and

$$\text{(8)} \qquad (\text{Lower bound}) = \bar{Y}(1 - \hat{\beta})$$

where the flexibility coefficients are

$$\text{(9)} \qquad \hat{\beta} = \frac{s}{\bar{Y}}\,.$$

In Equation (9), s is the sample standard deviation and $\bar{Y}$ is the sample mean of the historical acreage series. Thus $\hat{\beta}$ is defined as the sample coefficient of variation for the historical series. The procedure for determining flexibility restraints described in Equations (7), (8), and (9) was chosen for its statistical simplicity and because it results in relatively accurate predictions.

Assuming the RP model will choose either the upper or lower bound, these values may be viewed as alternative predictions with the optimization portion of the model being the device that chooses between them. Of what population parameters are these bounds actually estimates?

To answer this question, the assumed normal probability distribution function of Y_i is visualized as being divided into halves at the mean, μ. Then values in the upper half of the distribution may be denoted as Y_i'. Since a normally distributed population is assumed, the expected value of Y_i' is the mean of the upper half of this distribution function:

$$\text{(10)} \quad E(Y_i') = \mu + \sigma\sqrt{\frac{2}{\pi}} \quad \text{for } \mu < Y_i' < \infty\,.$$

In the equivalent form of Equation (1), the actual value of Y_i' in this half of the original population may be expressed as

$$\text{(11)} \qquad Y_i' = \mu + \sigma\sqrt{\frac{2}{\pi}} + u_i'.$$

Since the disturbance terms, u_i' now relate to only one-half of the population,

$$E(u_i') = 0 \qquad \text{for all } i$$

and

$$E(u_i' u_{i+s}')$$

$$\text{(12)} \qquad = \begin{cases} 0 & \text{for } s \neq 0 \text{ for all } i \\ \sigma^2\left(1 - \dfrac{2}{\pi}\right) & \text{for } s = 0 \text{ for all } i \end{cases}$$

The derivation of Equations (10) and (12) follows the procedure outlined by Anderson and Bancroft [1, Ch. 4], except that the appropriate truncated normal distributions[3] are now being worked with.

The necessary relations are now available to determine the mean square error of the upper bound (Equation 7) as an estimate of Y_{n+1}'. From Equations (7) and (11),

[3] One-half of the normal distribution has the functional form of

$$f(Y') = \frac{2}{\sqrt{2\pi\sigma^2}}\, e^{-(1/2\sigma^2)(Y'-\mu)^2} \qquad \text{for } \mu < Y' < \infty.$$

The mean of this population is defined as

$$E(Y') = \int_{\mu}^{\infty} Y' f(Y')\, dY'$$

or

$$E(Y') = \mu + \sigma\sqrt{\frac{2}{\pi}}\,.$$

The second moment for the truncated normal function is

$$E(Y'^2) = \int_{\mu}^{\infty} Y'^2 f(Y')\, dY'$$

or

$$E(Y'^2) = \sigma^2 + \mu^2 + \frac{2\mu\sigma\sqrt{2}}{\sqrt{\pi}}\,.$$

The variance of Y' is then

$$E(u'^2) = E(Y'^2) - [E(Y')]^2$$

or

$$E(u'^2) = \sigma^2\left[1 - \frac{2}{\pi}\right].$$

$$D^2(\text{Equation 7}) = E\left[\bar{Y}\left(1 + \frac{s}{\bar{Y}}\right) - \left(\mu + \sigma\sqrt{\frac{2}{\pi}} + u_{n+1}'\right)\right]^2.$$

Following the procedure used earlier in deriving Equation (6),

$$D^2(\text{Equation 7}) = \frac{\sigma^2}{n} + \sigma^2\left(1 - \frac{2}{\pi}\right) + \sigma^2\left(1 + \frac{2}{\pi}\right) - 2\sigma\sqrt{\frac{2}{\pi}}\,E(s)$$

$$(13)\qquad = \sigma^2\left(2 + \frac{1}{n}\right) - 2\sigma\sqrt{\frac{2}{\pi}}\,E(s).$$

The mean square error is a function of the number of years of data used in computing the mean. Choosing $n=10$ as an example, Hald [6, p. 299] showed that

$$(14)\qquad E(s) = 0.9728\sigma$$

because s is not an unbiased estimate of σ for small sample sizes. Equations (13) and (14) then give, for $n=10$

$$D^2(\text{Equation 7}) = \sigma^2(2.1 - 1.5524) = 0.5476\sigma^2.$$

The square root of this value is 0.7400 σ. This is the expected error if the RP model chooses the upper bound when, in fact, Y_{n+1} falls in the upper half of the population.

It is, of course, possible that the RP model will make the incorrect choice, that is, choose the lower bound when Y_{n+1} is in the upper half of the population. In this case, the mean square error becomes

$$D^2(\text{Equation 8})$$

$$(15)\qquad = \sigma^2\left(2 + \frac{1}{n}\right) + 2\sigma\sqrt{\frac{2}{\pi}}\,E(s).$$

Thus, when the RP model chooses the wrong bound, the last term of the mean square error is positive rather than negative as in Equation (13). For $n=10$, Equations (14) and (15) give

$$D^2(\text{Equation 8}) = 3.6524\sigma^2.$$

The square root of this value, 1.9111 σ, is the expected error when the RP model makes the wrong choice of bounds, that is, chooses the lower bound as an estimate of Y_{n+1}'.

An overall measure of error in the RP model may now be computed, assuming the probability of the model choosing the correct bound, p, is known. Defining this ***total expected error*** as δ, its value for the flexibility restraint procedure being used as an estimate of Y_{n+1}' is found by[4]

$$(16)\qquad \delta = (p[D^2(\text{Upper bound})] + (1 - p)[D^2(\text{Lower bound})])^{1/2}.$$

When $n=10$ the mean square errors computed in Equations (13) and (15) give

$$\delta = \sqrt{p(0.5476\sigma^2) + (1 - p)(3.6524\sigma^2)}.$$

As an example, assume $p=0.75$. Then

$$(17)\qquad \delta = \sqrt{1.3238\sigma^2} = 1.1506\sigma.$$

In this case, the recursive programming model is slightly less accurate than using the mean, $\bar{Y}$, as a prediction of Y_{n+1}, since earlier (Equation 6) the expected error of the mean as a prediction of Y_{n+1} was computed as $\sigma\sqrt{1+1/n}=1.0488\ \sigma$ for $n=10$. The expected error of the RP model is 1.1506 σ compared to 1.0488 σ for the mean in this example.

It is also possible, in this case, to compute the level of reliability (p) required by the RP model to provide a better estimate than merely using the mean as a prediction of Y_{n+1}. For the model now used, this level of reliability would be achieved by a p that is high enough for $\delta = 1.0488\ \sigma$ in Equation (17). The required p is 0.8221. In this case, the RP model must choose the correct bound over 82 percent of the time for its prediction to be as reliable as using the mean, $\bar{Y}$, as a prediction of Y_{n+1}.

This approach to RP is based on the use of a statistical prediction as the base for the flexibility restraints. The residual variation around

[4] This procedure may appear to consider only those errors associated with Y_{n+1} values in the upper half of the distribution. However, since p is defined as the probability of choosing the correct bound (the bound in the same half of the distribution as the actual Y_{n+1} value), Equation (16) is appropriate wherever Y_{n+1} falls.

this prediction is then further explained by the programming model via the correct choice of the upper or lower bound. The programming model explains an additional component of the residual variation by utilizing information not considered in making the statistical prediction of the base.

For this section, the population is assumed to be a series of normally distributed independent random elements with no time trend and the RP model is assumed to choose always either the upper or lower bound (Equations 1 to 4). The flexibility restraints are defined by Equations (7), (8), and (9). The total expected error follows uniquely from these assumptions, given that the sample estimates are based on 10 years of data.

Alternative Flexibility Restraints

It is possible to analyze a number of alternative methods for defining flexibility restraints in terms of the total expected error, δ, associated with each. As a generalization, flexibility restraints are made up of two components: (1) a base that is in some respects a prediction and (2) the bounds around this base, or the flexibility coefficients. Changing the method by which either component is determined will have an effect on the total expected error of the RP model.

Alternative bases

The mean, $\bar{Y}$, was chosen as the base of the flexibility restraints analyzed previously (Equations 7, 8, and 9). A base that may be more commonly used is the actual crop acreage for the current year, resulting in flexibility restraints defined as

$$\text{(18)} \qquad (\text{Upper bound}) = Y_n(1 + \hat{B})$$

and

$$\text{(19)} \qquad (\text{Lower bound}) = Y_n(1 - \hat{B})$$

with $\hat{B}$ defined as before in Equation (9).

For the particular population assumed, this procedure results in a larger total expected error because Y_n has a larger mean square error as a predictor of Y_{n+1} than does the mean, $\bar{Y}$. This argument may be developed by attributing the mean square error in Equations (13) and (15) to four components: (1) σ^2/n, the variance associated with the mean, $\bar{Y}$; (2) $\sigma - E(s)$, the expected error associated with the estimator s; (3) $\sigma^2(1-2/\pi)$, the variance of the actual Y_{n+1}' value in half of the population; and (4) the bias of the respective upper and lower bounds as predictors of Y_{n+1}'. This fourth component increases when the wrong bound is chosen by the RP model. Comparison of Equations (5) and (6) suggests that the first component of the mean square error increases from $\sigma^2(1+1/n)$ to $2\sigma^2$ when Y_n is used as the flexibility restraint base. Thus, the mean square errors for the flexibility restraints defined by Equations (18) and (19) as estimates of Y_{n+1}' are approximately[6]

$$\text{(20)} \qquad D^2(\text{Equation 18}) \simeq 3\sigma^2 - 2\sigma \sqrt{\frac{2}{\pi}}\, E(s)$$

and

$$\text{(21)} \qquad D^2(\text{Equation 19}) \simeq 3\sigma^2 + 2\sigma \sqrt{\frac{2}{\pi}}\, E(s).$$

For $n=10$ the expected error of Equation (18) as an estimate of Y_{n+1}' is 1.2032 σ, compared to 0.7400 σ when $\bar{Y}$ was used as the base. This is, of course, the error when the RP model chooses the correct bound. When the RP model chooses the incorrect lower bound, the expected error of Equation (19) as an estimate of Y_{n+1}' is 2.1336 σ.

Now, assuming that the probability of the RP model choosing the correct bound is $p=0.75$, Equation (16) suggests a total expected error of $\delta=1.4912\ \sigma$. This result compares to $\delta=1.1506\ \sigma$ when the mean was used as the base for the flexibility restraints instead of the current value, Y_n. Moreover, when the current year is used as the base, both mean square errors exceed $\sigma^2(1+1/n)$ from Equation (6) and the RP model is less accurate than using $\bar{Y}$ as the prediction, even for the case when $p=1.0$.

A similar technique may be used to approximate the total expected error associated with flexibility restraints using bases determined by any other statistical means, as long as the variance of the estimated base is known and the flexibility coefficient is $s/\bar{Y}$. Some examples would be using bases estimated by a simple linear trend, by a more general least squares model, or by more complex models to deal with

[6] These are approximations. Technically, Equations (20) and (21) show the mean square errors for upper and lower bounds defined as Y_n+s and Y_n-s respectively. Although the expected values of the Equation (18) and (19) bounds are the same, the predictions actually have higher mean square errors due to the use of an additional estimated parameter, $\bar{Y}$, in the flexibility coefficient. Hence, the actual mean square errors are underestimated by Equations (20) and (21).

autocorrelation, etc. In general, it is desirable to define the base for the flexibility coefficients as the best statistical prediction possible, as suggested earlier by Schaller and Dean [8, p. 68]. The respective mean square errors can be approximated in the same manner as Equations (20) and (21), recognizing that such estimates will be approximations of the true mean square errors since some covariance terms between estimated parameters may not equal zero or may not cancel in the general case. However, such approximations should be reasonably accurate and provide a valid evaluation of alternative flexibility restraint bases.

Alternative flexibility coefficients

As mentioned before, there are many alternative methods of computing the flexibility coefficients. The particular magnitude of the flexibility coefficients has a two-way effect on the total expected error through (1) changes in the bias of the particular bound as an estimate of Y_{n+1}' and in some instances through (2) changes in the amount of free play the RP model is given, compared with its ability to choose the correct bound. These two factors may affect the total expected error in different directions.

A common method of defining the flexibility coefficients is considered,

$$(22)\quad \bar{B} = \frac{\sum_{i}^{\bar{n}} \dfrac{Y_i - Y_{i-1}}{Y_i}}{\bar{n}} \quad \text{for all } Y_i > Y_{i-1}$$

and

$$(23)\quad \underline{B} = \frac{\sum_{i}^{\underline{n}} \dfrac{Y_i - Y_{i-1}}{Y_i}}{\underline{n}} \quad \text{for all } Y_i < Y_{i-1}$$

where $\bar{n}$ is the number of years in which the variable increased and $\underline{n}$ is the number of years in which the variable decreased. These equations define the upper flexibility coefficient as the average of the historical percentage increases and the lower flexibility coefficient as the average historical percentage decrease (Schaller's second method). The corresponding upper and lower bounds defined using the mean as a base are

$$(24)\quad (\text{Upper bound}) = \bar{Y}(1 + \bar{B})$$

and

$$(25)\quad (\text{Lower bound}) = \bar{Y}(1 - \underline{B}).$$

Since $\bar{B}$ and $\underline{B}$ are a form of order statistics involving the normal distribution, it is quite difficult to make exact estimates of mean square errors for flexibility restraints containing them. A rough approximation is available by working with an alternative flexibility coefficient with the same general characteristics as $\bar{B}$ ($\underline{B}$). From Equation (5) the variance of the difference between two random and independently distributed variables is $2\sigma^2$. Thus,

$$(26)\quad \bar{B} \text{ and } \underline{B} \simeq \sqrt{2}\,\frac{s}{\bar{Y}}$$

a form that is more convenient to work with.

This approximation suggests that using the flexibility coefficients $\bar{B}$ and $\underline{B}$ results in an even larger bias of the upper bound as the estimate of Y_{n+1}' than does use of the coefficient of variation, Equation (9). For $\bar{B}$ and $\underline{B}$, the variance of the flexibility coefficients is also higher since the data are split into increasing and decreasing groups and the flexibility coefficients computed separately for the two smaller groups; as a result the effective sample sizes ($\bar{n}$ and $\underline{n}$) are smaller.

The mean square errors of the Equations (24) and (25) flexibility restraints using the Equation (26) approximation are as follows: first, the mean square error of the upper bound as an estimate of Y_{n+1}' is

$$D^2(\text{Equation 24})$$
$$\simeq E\left[\bar{Y}\left(1 + \sqrt{2}\,\frac{s}{\bar{Y}}\right) - \left(\mu + \sigma\sqrt{\frac{2}{\pi}} + u_{n+1}'\right)\right]^2$$
$$(27)\quad \simeq \sigma^2\left(3 + \frac{1}{n}\right) - \sigma\,\frac{4}{\sqrt{\pi}}\,E(s).$$

For $n = 10$, the mean square error becomes

$$D^2(\text{Equation 24}) \simeq \sigma^2(3.1 - 2.1954) = 0.9046\sigma^2.$$

This value is, as expected, higher than the comparable value from Equation (13) because $\bar{B}$ has a larger bias and variance than $\hat{B}$.

The reader may verify that the mean square error for the lower bound as an estimate of Y_{n+1}' is

$$D^2(\text{Equation 25}) \simeq 5.2954\sigma^2.$$

For $p=0.75$, these mean square errors suggest a total error of $\delta=1.4150\ \sigma$ using $\bar{B}$ and B compared to $\delta=1.1506\ \sigma$ when the flexibility coefficient $\hat{B}$ was used (Equation 17). For this population, defining the flexibility coefficients as the average percentage increase (decrease) would appear to be inferior to defining them as the estimated coefficient of variation, $\hat{B}$.

There is, however, a brighter side. It is possible to use the tools that have been developed to define flexibility coefficients specifically to minimize the total expected error, δ. For the population being considered, this is accomplished by defining

$$\tilde{B} = \frac{Ks}{\bar{Y}} \tag{28}$$

where K is chosen to minimize the total expected error of the recursive programming model. Flexibility restraints of the form

$$(\text{Upper bound}) = \bar{Y}(1+\tilde{B}) \tag{29}$$

and

$$(\text{Lower bound}) = \bar{Y}(1-\tilde{B}) \tag{30}$$

will be considered for this example since $\bar{Y}$ is a better base than Y_n for the assumed population.

In a manner similar to the derivation of Equation (27) the mean square error of Equation (29) as an estimate of Y_{n+1}' is

$$\begin{aligned} D^2(\text{Equation 29}) &= \sigma^2\left(1+\frac{1}{n}+K^2\right) \\ &\quad - 2K\sigma\sqrt{\frac{2}{\pi}}\,E(s) \end{aligned} \tag{31}$$

while the mean square error of Equation (30) as an estimate of the same value has a positive sign for the last term.

The problem is then one of finding the value of K for which the total expected error, δ, is a minimum. Since, in this case, the value of K that will minimize δ will also minimize δ^2, the easiest procedure is to set the derivative of δ^2 with respect to K equal to zero and to solve for K. From Equations (16) and (31),

$$\delta^2 = K^2\sigma^2 + K(2-4p)\sigma\sqrt{\frac{2}{\pi}}\,E(s) + \sigma^2\left(1+\frac{1}{n}\right)$$

and

$$\frac{d\delta^2}{dK} = 2K\sigma^2 + (2-4p)\sigma\sqrt{\frac{2}{\pi}}\,E(s) = 0.$$

The second derivative is positive so this value of K minimizes δ^2. For $n=10$,

$$K = 1.5524p - 0.7762. \tag{32}$$

The optimum size of K is found to be a function of p, the probability that the RP model will choose the correct bound. For $p=1.0$, the optimum size for K is 0.7762. For $p=0.5$, $K=0$ and the total expected error becomes equivalent to $\sigma\sqrt{1+1/n}$. This is the same error discovered when the mean was used as the prediction in Equation (6). Thus, for all $p\leqq 0.5$, bounds computed with $K=0$ would give the lowest total expected error; these are equivalent to an equality bound in the RP model. Equation (32) points out the trade-off between (1) the accuracy of the bound as an estimate of Y_{n+1}' and (2) the amount of free play the RP model is given. Narrower bounds should be used as the probability of the model choosing the correct bound declines. When the probability (p) reaches 0.5 or lower, the most accurate estimate is provided by simply using the mean ($\bar{Y}$) as the prediction.

The RP model should, of course, have the biggest relative advantage over other procedures when $p=1.0$. In this case, K would equal 0.7762 from Equation (32) and the resulting mean square error of Equation (29) is

$$\begin{aligned} D^2(\text{Equation 29}) &= E\left[\bar{Y}\left(1+0.7762\frac{s}{\bar{Y}}\right) - \left(\mu+\sigma\sqrt{\frac{2}{\pi}}+u_{n+1}'\right)\right]^2 \\ &= 0.4975\sigma^2 \end{aligned}$$

for $n=10$. Therefore, when $p=1.0$, this procedure results in $\delta=0.7054\ \sigma$. In this case the RP model provides estimates with higher accuracy than any of the alternative predictive models considered. This case substantiates the theoretical value of recursive programming as a predictive tool.

Summary

Table 1 presents the total expected error of the recursive programming estimate that would accompany the various flexibility restraint

Table 1. Total expected error, δ, for different flexibility restraints and p values with n = 10

Base	p	Flexibility coefficient			
		$\hat{B}=\frac{s}{\bar{Y}}$	$\bar{B}, B \cong \sqrt{2}\frac{s}{\bar{Y}}$	$\tilde{B}=0.7762\frac{s}{\bar{Y}}$	$\tilde{B}'=0.3881\frac{s}{\bar{Y}}$
$\bar{Y}$	1.00	0.7400 σ	0.9511 σ	0.7054 σ	0.8051 σ
	.75	1.1506 σ	1.4150 σ	1.0488 σ	0.9744 σ
	.50	1.4491 σ	1.7607 σ	1.3048 σ	1.1183 σ
	0	1.9111 σ	2.3012 σ	1.7051 σ	1.3613 σ
Y_n	1.00	1.2032 σ	1.3434 σ	1.1822 σ	1.2442 σ
	.75	1.4912 σ	1.7036 σ	1.4142 σ	1.3599 σ
	.50	1.7321 σ	2.0000 σ	1.6132 σ	1.4665 σ
	0	2.1336 σ	2.4891 σ	1.9513 σ	1.6592 σ

procedures which have been discussed, given the hypothetical population of Equations (1) through (4). The tabled values are a function of the probability, p, that the RP model will choose the correct bound, and assume a 10-year sample of historical data, that is, $n=10$. Total expected errors are presented for four flexibility coefficients in combination with two bases, $\bar{Y}$ and Y_n. Of the flexibility coefficients considered, $\tilde{B}$ with $K=0.7762$ results in the lowest expected error when the correct bound is chosen, that is, when $p=1.0$. In this case, $\delta=0.7054\ \sigma$. With $p=1.0$, the expected error increases for either larger ($\hat{B}$) or smaller ($\tilde{B}'$) flexibility coefficients with the use of average percentage changes ($\bar{B}$ and B) as flexibility coefficients resulting in the highest total expected errors.

For $p=0.75$, the flexibility coefficient $\tilde{B}'$ with $K=0.3881$ gives the best estimate. The value of 0.3881 for K was specifically chosen to minimize the error for $p=0.75$ and it, therefore, provides a lower error than any of the other flexibility coefficients for $p=0.75$. Since $\tilde{B}'$ is smaller than any of the other flexibility coefficients, it shows the effect of using narrow bounds—a large decrease in error when the incorrect bound is chosen by the RP model at the expense of a small increase in total expected error when $p=1.0$. Of course, whenever the expected value of $p \leqq 0.5$, $K=0$ by Equation (32) and the total expected error could be held to 1.0488 σ.

None of the flexibility restraints using the current year, Y_n, as the base result in estimates more accurate than using the mean, $\bar{Y}$. In fact, for the population assumed, simply using $\bar{Y}$ as the prediction of Y_{n+1} results in lower total expected error than any RP model procedure using Y_n as the base for the flexibility restraints.

Thus, the analysis suggests the critical importance of three items in determining the total expected error of recursive programming models: (1) the reliability of the model in choosing the correct bound, (2) the variance of the base of the flexibility restraint, and (3) the magnitude of the flexibility coefficients. The techniques outlined provide a basis for estimating the total expected error associated with many alternative flexibility restraint bases, flexibility coefficients, and distribution functions of the unexplained variation.

References

[1] ANDERSON, R. L., AND T. A. BANCROFT, *Statistical Theory in Research*, New York, McGraw-Hill Book Co., Inc., 1952.

[2] DAY, RICHARD H., "An Approach to Production Response," *Agr. Econ. Res.* 14:134–148, Oct. 1962.

[3] ———, *Recursive Programming and Production Response*, Amsterdam, North-Holland Pub. Co., 1963.

[4] ———, "Recursive Programming and Supply Prediction," in *Agricultural Supply Functions—Estimating Techniques and Interpretation*, eds. Earl O. Heady, C. B. Baker, H. G. Diesslin, *et al.*, Ames, Iowa State University Press, 1961.

[5] GATES, JOHN M., AND MARVIN W. KOTTKE, "The Dynamics of Milk Supply in Southeast New England," Storrs (Conn.) Agr. Exp. Sta. Res. Bull. 395, March 1966.

[6] HALD, A., *Statistical Theory with Engineering Applications*, New York, John Wiley & Sons, Inc., 1952.

[7] HENDERSON, JAMES M., "The Utilization of Agricultural Land: A Theoretical and Empirical Inquiry," *Rev. Econ. & Stat.* 41:242–259, Aug. 1959.

[8] SCHALLER, W. NEILL, AND GERALD W. DEAN, "Predicting Regional Crop Production—An Application of Recursive Programming," USDA, ERS Tech. Bull. 1329, April 1965.

[9] SCHALLER, W. NEILL, "The Meaning and Estimation of 'Flexibility' and 'Technology' Restraints in Programming Models of Production," USDA, ERS mimeo., 1964.

[10] SHARPLES, JERRY A., AND W. NEIL SCHALLER, "Predicting Short-Run Aggregate Adjustment to Policy Alternatives," *Am. J. Agr. Econ.* 50:1523–1536, Dec. 1968.

[11] ZEPP, GLENN A., AND ROBERT H. MCALEXANDER, "Predicting Aggregate Milk Production: An Empirical Study," *Am. J. Agr. Econ.* 51:642–649, Aug. 1969.

A Polynomial Lag Formulation of Milk Production Response*

DEAN CHEN, RICHARD COURTNEY, AND ANDREW SCHMITZ

For much of agricultural production, output response to some given price change is hypothesized to increase first through time and then decline. To detect this type of response, a polynomial price lag model is estimated for milk production. For comparison purposes, a geometrically declining price lag model is also estimated. Although the estimates of long-run supply elasticities do not critically depend on the type of model used, the response for each period of time and for various short-run intervals does.

PRODUCER PRICES in most United States fluid milk markets are regulated by either federal milk marketing orders or state milk control programs. Thus, any price change should be evaluated, at least partially, for its impact on the quantity of milk produced. Estimates of the responsiveness of milk production to price changes provide useful information for administrators who try to provide an adequate supply of milk to consumers and at the same time maintain a "reasonable" balance between milk production and consumption.

During the last decade, many quantitative studies of milk production response have been conducted.[1] In a well-known paper, Brandow [3] used single equation regression analysis to estimate supply relationships for milk produced in the United States. Later, Halvorson [13], also using single-equation least squares, estimated milk production per cow as a function of the milk-feed price ratio, hay production, and cow numbers and found production to be highly price inelastic. In a following study, Halvorson [14], using a Nerlovian distributed lag model, estimated by least squares the short- and long-run price elasticities of United States milk production to be in the range of 0.15 to 0.30 and 0.35 to 0.50, respectively. Kottke [17] and Ladd and Winter [19] have also used single equation regression analysis to estimate supply response. Recently, Wilson and Thompson [24] used a simultaneous equation model to derive both supply and demand relationships for milk.

Although much of this work has incorporated current and/or lagged prices as key variables explaining short- and long-run production response, it has been limited to specifying nonflexible price lag structures. This implicitly assumes that the greatest increase in output from a price increase is forthcoming in the first period. However, if monthly time periods are considered, a recent linear programming analysis by Kelley and Knight [16] suggests that this is a highly questionable assumption. Yet, despite the limitation imposed by a geometrically declining lag structure, Zepp and McAlexander [25] have shown that regression analysis is still more appropriate than linear and recursive programming for estimating and predicting the impact of price changes on fluid milk production.

In this paper milk production response functions are empirically estimated using a distributed lag formulation which allows a greater degree of flexibility in the lag structure than does the partial adjustment model formulated by Nerlove [21, 22]. For comparison purposes results are derived using Nerlove's partial adjustment hypothesis. By specifying and estimating a more flexible lag price structure, supply response estimates derived using regression analysis can perhaps be improved.

Milk Production Distributed Lag Models

The quantity of milk produced in a given time period is hypothesized as a function of the price of milk, prices of inputs used in milk production, returns obtainable from competing commodities, and the existing state of milk production technology. However, in milk production as in many other products, there is a

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[1] It is beyond the scope of this paper to evaluate the alternative techniques used by researchers for studying supply response. An excellent comparison is contained in Colyer [6].

DEAN CHEN *is an economist with the Federal Reserve Bank, San Francisco;* RICHARD COURTNEY *is an assistant agricultural economist in the Experiment Station and on the Giannini Foundation, University of California, Berkeley; and* ANDREW SCHMITZ *is an associate professor of agricultural economics at the University of California, Berkeley. This study was completed when Dean Chen was a visiting associate economist in the Department of Agricultural Economics, University of California, Berkeley.*

lagged response to a price change due to the nature of the underlying production process. Some adjustments can be made in a very short time period, while others require considerably more time. The emphasis of this paper is on determining the nature of the lagged output response resulting from a change in product price.

Excluding for the moment variables other than product price, a general distributed lag model can be written as

$$(1) \qquad Q_t = \sum_{\tau=0}^{k} \beta_\tau P_{t-\tau}$$

where

Q_t = output at time t
$P_{t-\tau}$ = price at time $t-\tau$
k = number of periods covered by the lag function

and

β_τ = the coefficients of the lag structure; β_0, $\beta_1, \cdots, \beta_k$. Thus, there are $k+1$ coefficients to be determined.

Geometrically declining lag

In his early work on investment, Koyck [18] assumed that β_τ in equation (1) has the special form

$$(2) \qquad \beta_\tau = a\lambda^\tau$$

where $0 \leq \lambda < 1$. Among those who have used this geometrically declining distributed lag structure are Cagan [4], Friedman [9], and Nerlove [21, 22]. Of relevance to this study is the partial adjustment model formulated by Nerlove

$$(3) \quad Q_t - Q_{t-1} = \gamma(Q_t^* - Q_{t-1}) \qquad 0 \leq \gamma < 1$$

where Q_t^* is the "desired" level of output in time t and is expressed as

$$(4) \qquad Q_t^* = c + bP_t.$$

The solution to equation (3) is

$$(5) \qquad Q_t = \sum_{\tau=0}^{\infty} \gamma(1-\gamma)^\tau Q_{t-\tau}^*.$$

Substituting equation (4) into equation (5) gives

$$(6) \qquad Q_t = c' + b \sum_{\tau=0}^{\infty} \gamma(1-\gamma)^\tau P_{t-\tau}.$$

That is, the weight assigned to any given price $P_{t-\tau}$ is $b\gamma(1-\gamma)^\tau$. With reference to equation (2),

$$(7) \quad \beta_\tau = b\gamma(1-\gamma)^\tau \qquad \text{for } 0 \leq \gamma < 1$$

which indicates that β_τ, as a function of τ, declines geometrically.

The major problems encountered in using a model of the above form have been discussed elsewhere by Griliches [10, 11] and Hall and Sutch [12]. One such problem is that the lag formulation itself is restricted by the geometrical specification.

More flexible distributed lags

To obtain more flexible specifications of distributed lags, de Leeuw [7, 8] used a finite inverted V lag as well as the sum of two finite geometric lags. These have different rates of decline and coefficients of opposite sign. Solow [23] suggested that the points on a lag structure lie along a Pascal probability distribution. Later Jorgenson [15] described a class of lag functions as rational since they can be described as the ratio of two finite polynomials in the lag operation.

An alternative to the above is a finite distributed lag whose coefficients are restricted to lie on a polynomial of low order. This was first suggested by Almon [1], and modifications have been made by Bischoff [2] and Modigliani and Sutch [20]. Recently, Hall and Sutch [12] suggested a more flexible lag structure which includes both a polynomial and a rational function.

In a generalized polynomial lag model the lagged weights are given by

$$(8) \quad \beta_\tau = \alpha_0 + \alpha_1\tau + \alpha_2\tau^2 + \cdots + \alpha_N\tau^N$$

where N is the order of the polynomial. Equation (1) can then be rewritten as

$$(9) \quad Q_t = \sum_{\tau=0}^{k} (\alpha_0 + \alpha_1\tau + \alpha_2\tau^2 + \cdots + \alpha_N\tau^N) P_{t-\tau}.$$

It is generally considered that a low-order polynomial is appropriate for most econometric work. Certainly, these types of models are easier to handle computationally. In this paper a second order finite polynomial is used. Equation (9) then becomes

$$(10) \qquad Q_t = \sum_{\tau=0}^{k} (\alpha_0 + \alpha_1\tau + \alpha_2\tau^2) P_{t-\tau}.$$

In this formulation

$$(11) \qquad \beta_\tau = \alpha_0 + \alpha_1\tau + \alpha_2\tau^2.$$

A further restriction on β_τ is that $\beta_\tau = 0$ when $\tau = k$. That is,

$$(12) \qquad \alpha_0 + \alpha_1 k + \alpha_2 k^2 = 0.$$

This restriction is imposed since it is assumed that, beyond some length of time period k, price changes no longer affect current production. In the empirical section of this study, various lengths of lag periods are considered in order to determine the most appropriate length of lag. Solving equation (12) for α_0 and substituting into equation (11) gives

$$(13) \quad \beta_\tau = -\alpha_1 k - \alpha_2 k^2 + \alpha_1\tau + \alpha_2\tau^2$$

$$(14) \qquad = \alpha_1(\tau - k) + \alpha_2(\tau^2 - k^2).$$

Equation (10) can then be written as

$$(15) \qquad Q_t = \alpha_1 \sum_{\tau=0}^{k} (\tau - k)P_{t-\tau} + \alpha_2 \sum_{\tau=0}^{k} (\tau^2 - k^2)P_{t-\tau}.$$

In equation (15) the price variables for which coefficients are estimated are

$$\sum_{\tau=0}^{k} (\tau - k)P_{t-\tau} \quad \text{and}$$

$$\sum_{\tau=0}^{k} (\tau^2 - k^2)P_{t-\tau}.\text{[2]}$$

For estimation purposes, it is possible to expand equations (6) and (15) to incorporate nonprice variables which can be estimated by ordinary least squares regression analysis. In this paper the very recent Hall and Sutch [12] estimation procedure is used as a more direct way of producing Almon's results [1] since it avoids using Lagrange interpolation polynomials.

Empirical Results

Both the geometric and polynomial distributed lag models were fitted to California quarterly milk production data. The following variables were included: prices of market milk, dairy feed, and cutter and canner cattle; an index of prices received by farmers for all farm products; average weekly gross earnings for workers in manufacturing; and, as alternative measures of technological change, time and an index number of farm production per man-hour for milk cows. Preliminary results showed that some of these variables were statistically insignificant and, hence, were excluded. Results are presented for the following geometric and polynomial lag models:

$$(16) \qquad Q_t = \alpha_0 + \alpha_1 P_t + \alpha_2 S + \alpha_3 Q_{t-1}$$

$$(17) \qquad Q_t = a_0 + a_1 \sum_{\tau=0}^{k} (\tau - k)P_{t-\tau} + a_2 \sum_{\tau=0}^{k} (\tau^2 - k^2)P_{t-\tau} + a_3 S + a_4 Z$$

where

Q_t = quarterly commercial production of market milk in California, 1953–1968 (10 million pound units)[3]

$P_{t-\tau}$ = ratio of average quarterly price paid to producers for market milk, f.o.b. ranch, California (dollars per hundredweight × 20 hundredweight ÷ tons) to average quarterly price paid by farmers for 16 percent protein dairy feed, California (dollars per ton)[4]

S = 0 for the first and fourth quarters; 1 for the second and third quarters

and

Z = technology variable: T_t = time which is set equal to 1 for the first quarter in 1953; as an alternative, V_t = index of farm production per man-hour for milk cows.[5]

The results based on the polynomial lag formulation are presented in Table 1 for length of lags 5 through 9. It was impossible to compute results for more than 9 lagged periods due to the high degree of multicollinearity.[6]

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[2] For estimation purposes the lagged weights were estimated as

$$W_1 = \sum_{\tau=0}^{k} (k - \tau)P_{t-\tau} \quad \text{and} \quad W_2 = \sum_{\tau=0}^{k} (k^2 - \tau^2)P_{t-\tau}.$$

[3] Data obtained from California Crop and Livestock Reporting Service, *Manufactured Dairy Products, Milk Production Utilization, and Prices* (Sacramento), various issues.

[4] Milk prices same as above. Feed prices obtained from U. S. Agricultural Marketing Service, *Agricultural Prices*, various issues.

[5] Index of farm production obtained from U. S. Department of Agriculture, *Changes in Farm Production and Efficiency*, Statistical Bulletin 233, 1969.

[6] For periods longer than 9, it was impossible to invert the matrix of sums of squares and cross-products due to the high degree of correlation between W_1 and W_2.

Table 1. Regression estimates for California milk production response, polynomial lag formulations, 1953–1968[a]

Lag period	Constant term	W_1[b]	W_2[c]	S	V_t	T_t	R^2
$k=5$	−209.025	−3.450 (−0.123)	3.495 (0.777)	11.023 (2.705)*			0.803
	161.731	6.392 (0.348)	−1.433 (−0.614)	7.463 (3.769)*	0.816 (9.096)*		0.926
	136.912	−6.348 (−0.532)	0.600 (0.405)	7.875 (6.016)*		1.563 (16.105)*	0.968
$k=6$	−218.138	−17.050 (−0.773)	4.015 (1.373)****	9.669 (2.815)*			0.820
	140.073	−1.222 (−0.076)	−0.177 (−0.102)	8.085 (4.193)*	0.766 (8.071)*		0.925
	125.959	−10.614 (−1.017)	1.052 (0.943)	7.982 (6.227)*		1.516 (14.574)*	0.967
$k=7$	−223.977	−21.210 (−1.226)	3.525 (1.801)***	8.316 (2.445)**			0.837
	139.459	−2.991 (−0.258)	0.077 (0.070)	8.788 (4.760)*	0.750 (7.758)*		0.930
	121.956	−7.487 (−0.958)	0.667 (0.907)	8.141 (6.484)*		1.475 (13.639)*	0.967
$k=8$	−223.960	−17.792 (−1.340)****	2.517 (1.921)***	7.998 (2.428)**			0.851
	147.521	−1.153 (−0.130)	−0.054 (−0.072)	8.263 (4.548)*	0.751 (7.530)*		0.929
	126.649	−3.152 (−0.509)	0.241 (0.463)	7.987 (6.240)*		1.470 (12.818)*	0.964
$k=9$	141.390	−0.192 (−0.025)	−0.080 (−0.135)	7.529 (4.189)*	0.723 (7.265)*		0.930
	122.426	−1.777 (−0.323)	0.128 (0.308)	7.668 (5.895)*		1.430 (12.086)*	0.963

[a] Numbers in parentheses are t values.

[b] $W_1 = \sum_{\tau=0}^{k} (k-\tau)P_{t-\tau}$.

[c] $W_2 = \sum_{\tau=0}^{k} (k^2-\tau^2)P_{t-\tau}$.

* Statistically significant at the 1 percent level.
** Statistically significant at the 5 percent level.
*** Statistically significant at the 10 percent level.
**** Statistically significant at the 20 percent level.

When a measure of technological change is included, regardless of the length of lag considered, the coefficients (W_1, W_2) of the milk-feed price ratio are statistically insignificant. However, coefficients for the seasonal effect and either measure of technology are significant at the 1 percent level. When technology is excluded, W_1 and W_2 are significant for the 8-period lag model at the 20 and 10 percent levels, respectively. In the 6-period lag model, W_2 is significant at the 20 percent level, while in the 7-period model it is significant at the 10 percent level. Except for the 8-period lag model, the coefficient on W_1 is insignificant, at least at the 20 percent level. For all lagged periods, the coefficient for the seasonal effect is significant at the 5 percent level.

Results from the Nerlovian formulation are

$$
\begin{aligned}
Q_t = &-39.211 + 46.564P_t + 7.642S + 0.85Q_{t-1} \\
&(-4.81) \quad (4.87) \quad (6.59) \quad (30.70)
\end{aligned}
\tag{18}
$$

$$R^2 = 0.925.$$

Here, all the coefficients are statistically significant as indicated by the bracketed t values. When technology is included in the polynomial

lag model, the results are substantially different in that the milk-feed prices have no effect on the level of milk production. This is not true, however, when technology is excluded. There is little basis for deciding which model is "best." The equation from Table 1, where $k=8$ and a measure of technology is excluded, is selected for comparison and illustrative purposes since both W_1 and W_2 were statistically significant. In this equation

$$W_1 = 8P_t + 7P_{t-1} + 6P_{t-2} + 5P_{t-3} + 4P_{t-4} + 3P_{t-5} + 2P_{t-6} + P_{t-7}$$

$$W_2 = 64P_t + 63P_{t-1} + 60P_{t-2} + 55P_{t-3} + 48P_{t-4} + 39P_{t-5} + 28P_{t-6} + 15P_{t-7}.$$

The regression coefficients for W_1 and W_2 are -17.792 and 2.517.

If the coefficients are "unscrambled" according to the formulas for W_1 and W_2, the results are

Lag	*Linear*	*Quadratic*	*Total*
t	−142.336	161.088	18.752
$t-1$	−124.544	158.571	34.027
$t-2$	−106.752	151.020	44.268
$t-3$	− 88.960	178.435	49.475
$t-4$	− 71.168	120.816	49.648
$t-5$	− 53.376	98.163	44.787
$t-6$	− 35.584	70.476	34.892
$t-7$	− 17.792	37.755	19.963

The estimated equation can then be rewritten as

$$\begin{aligned} Q_t = {} & -223.960 + 7.998S + \underset{(.830)}{18.752P_t} + \underset{(3.144)}{34.027P_{t-1}} \\ & + \underset{(15.325)}{44.268P_{t-2}} + \underset{(8.060)}{49.475P_{t-3}} \\ & + \underset{(4.796)}{49.648P_{t-4}} + \underset{(3.940)}{44.787P_{t-5}} + \underset{(3.515)}{34.892P_{t-6}} \\ & + \underset{(3.119)}{19.963P_{t-7}}. \end{aligned} \tag{19}$$

Except for the coefficient on P_t, all of the other coefficients are statistically significant at the 5 percent probability level as indicated by the bracketed t values.[7] It appears that a price change within any given time period has little impact on production with that period. A price change at time t has its maximum effect on production four periods later. Beyond four time periods, the impact on production becomes less and less. These results appear "reasonable" in view of *a priori* knowledge of the dairy industry.

Price elasticities and lagged response

For the Nerlovian formulation the short- and long-run price elasticities are 0.381 and 2.541, respectively. For the polynomial lag a price elasticity is derived for each time period as well as an elasticity which covers the entire response period considered. The elasticity of supply associated with a change in relative prices at any point in time t can be calculated as:

$$e_\tau = \frac{\partial Q_t}{\partial P_{t-\tau}} \cdot \frac{\overline{P}}{\overline{Q}} \qquad \tau = 0, 1, \cdots, k. \tag{20}$$

The cumulated price elasticity for all k quarters is

$$e_s = \sum_{\tau=0}^{k} \frac{\partial Q_t}{\partial P_{t-\tau}} \frac{\overline{P}}{\overline{Q}} \,. \tag{21}$$

P and Q are set at their respective means for the entire time period considered. The derived elasticities are given in Table 2.

The results show that, for a 1 percent change in the milk-feed price ratio at time t, the supply elasticity for t is 0.16. This value reaches a maximum of 0.42 at $t+3$ and $t+4$ and declines to 0.17 at $t+7$. However, the total increase in supply from a 1 percent change in price at time t is given by the cumulated elasticity which is 2.53. It is interesting to note that the short-run elasticity of 0.38 derived from the Nerlovian model is that obtained from the polynomial lag formulation for the time periods $t+2$ and $t+5$. However, the elasticities computed for periods $t+3$ and $t+4$ are greater than this. Also, the long-run elasticity of 2.541, based on the geometrically declining lag structure, is approximately equal to the cumulated elasticity derived from the polynomial lag model. Hence, for the models selected, the long-run response estimates do not depend critically on whether a geometrically declining or a polynomial lag price structure is assumed. However, the re-

[7] The t values for β_τ are computed as follows:

$$\beta_\tau = [\alpha_1(\tau - k) + \alpha_2(\tau^2 - k^2)]$$

where the variance of β_τ is

$$\begin{aligned} \text{Var}(\beta_\tau) &= \text{Var}[\alpha_1(\tau - k) + \alpha_2(\tau^2 - k^2)] \\ &= (\tau - k)^2 \text{var}(\alpha_1) + (\tau^2 - k^2)^2 \text{Var}(\alpha_2) \\ &\quad + 2(\tau - k)(\tau^2 - k^2)\,\text{Cov}(\alpha_1\alpha_2). \end{aligned}$$

Then:

$$t_{\beta_\tau} = \frac{\beta_\tau}{\sqrt{\text{Var}\,\beta_\tau}} \,.$$

Table 2. Estimated price elasticities derived from the polynomial lag formulation

Time period	e_τ	Time period	e_τ
t	0.16	$t+4$	0.42
$t+1$	0.29	$t+5$	0.38
$t+2$	0.38	$t+6$	0.30
$t+3$	0.42	$t+7$	0.17
Aggregate elasticity (e_s) = 2.53			

sponse for each period of time and for various short-run intervals does. This can be seen clearly from Figure 1 in which are plotted the results from both the geometric and the polynomial lag formulations. Because of its specification, the geometric lag continually declines; hence, output response decreases with time. However, the polynomial lag model suggests that the rate of output response from a price change first increases and then declines. This type of output response does not seem to be unrealistic for milk production since it appears unlikely that the greatest marginal output from a given change in price is forthcoming in the immediate period after the price change.

Because of seasonal price changes, it may be important to know the "intermediate" effects on production from a price change rather than the long-run effect. From Figure 1, if one wants to know, for example, the total output forthcoming during periods $t+1$ through $t+4$ from a price change, the result would be substantially different, depending on which type of distributed lag formulation is used. The results here suggest that for the initial periods the estimated production increase due to a price change is much lower if derived from a geometrically declining lag model rather than from one which is based on a polynomial lag formulation.

Conclusions

Milk production response for both a polynomial and a geometrically declining distributed lag price structure was estimated. The polynomial lag formulation is a relatively recent development which likely explains why it has not been used extensively in estimating supply response. The authors feel that, for much of agricultural production, output response to some given price change first increases through time and then declines. This certainly appears to be true for dairying. However, only if a flexible price lag structure, such as the polynomial formulation, is used can one hope to detect this type of output response.

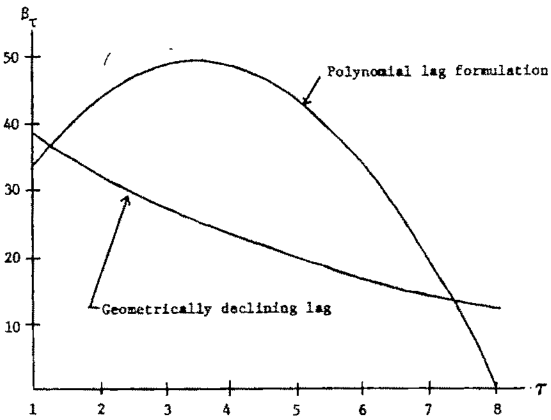


Figure 1. Geometric and polynomial lags for milk production response

Despite the added advantages offered by the polynomial lag formulation, supply response estimation still appears to be an extremely problematic research area for at least two reasons. First, as Griliches [11] recently pointed out, "Most distributed lag models have almost no or only a very weak theoretical underpinning." Thus, one has little information as to what type of lag models to accept or reject. It is for this reason that results are presented here which differ markedly depending on whether or not a measure of technology is included. One has little information to decide which of the models presented is best. The model in which technology was excluded was selected largely for illustrative and comparison purposes. Second, most distributed lag models are derived from time series data in which likely more than one price change occurred. Thus, results derived from these data do not really reveal the output response for a once-and-for-all change in price; rather, the function estimated indicates the responsiveness of production from several price changes. Consequently, the computed price elasticities do not have the same meaning as those presented in conventional theory.[8] In view of these limitations, one is admittedly searching for a black cat in a dark room when doing supply response studies. It is the authors' hope that the black cat actually exists.

[8] For a further discussion of this point, see Cochrane [5].

References

[1] ALMON, SHIRLEY, "The Distributed Lag between Capital Appropriations and Expenditures," *Econometrica* 33:178–196, Jan. 1965.

[2] BISCHOFF, C. W., "Elasticities of Substitution, Capital Malleability, and Distributed Lag Investment Functions," paper presented at the Econometric Society Meetings, San Francisco, Dec. 1966.

[3] BRANDOW, G. E., *Changes in Milk Production in the United States, 1924–51*, Pa. Agr. Exp. Sta. Progress Report 97, Feb. 1953.

[4] CAGAN, PHILLIP, "The Monetary Dynamics of Hyperinflation," in *Studies in the Quantity Theory of Money*, ed. Milton Friedman, Chicago, University of Chicago Press, 1956, pp. 25–117.

[5] COCHRANE, WILLARD W., "Conceptualizing the Supply Relation in Agriculture," *J. Farm Econ.* 37:1161–1176, Dec. 1955.

[6] COLYER, DALE, "Analytical Methods in the Study of Milk Supply," in *Demand and Supply Analysis Tools in Dairy Price and Income Policy*, Proceedings of seminar, Chicago, Sept. 1969, pp. 51–61.

[7] DE LEEUW, FRANK, "The Demand for Capital Goods by Manufacturers: A Study of Quarterly Time Series," *Econometrica* 30:407–423, July 1962.

[8] ———, "A Model of Financial Behavior," in *Brookings Quarterly Econometric Model of the United States Economy*, ed. J. S. Duesenberry, *et al.*, Chicago, Rand McNally and Co., 1965, pp. 465–530.

[9] FRIEDMAN, MILTON, *A Theory of the Consumption Function*, Princeton, Princeton University Press, 1957.

[10] GRILICHES, ZVI, "A Note on Serial Correlation Bias in Estimates of Distributed Lags," *Econometrica* 29: 65–73, Jan. 1961.

[11] ———, "Distributed Lags: A Survey," *Econometrica* 35:16–49, Jan. 1967.

[12] HALL, ROBERT E., AND RICHARD C. SUTCH, "A Flexible Infinite Distributed Lag," Working Paper 124, Committee on Econometrics and Mathematical Economics, Center for Research in Management Science, University of California, Berkeley, Feb. 1968.

[13] HALVORSON, HARLOW W., "The Supply Elasticity of Milk in the Short Run," *J. Farm Econ.* 39:1186–1197, Dec. 1955.

[14] ———, "The Response of Milk Production to Price," *J. Farm Econ.* 40:1101–1113, Dec. 1958.

[15] JORGENSON, DALE W., "Rational Distributed Lag Functions," *Econometrica* 34:135–149, Jan. 1966.

[16] KELLEY, PAUL L., AND DALE A. KNIGHT, "Short-Run Elasticities of Supply for Milk," *J. Farm Econ.* 47: 93–104, Feb. 1965.

[17] KOTTKE, MARVIN W., *Forces Influencing the Connecticut Supply of Milk*, Storrs (Conn.) Agr. Exp. Sta. Bull. 341, June 1959.

[18] KOYCK, LEENDERT MARIUS, *Distributed Lags and Investment Analysis*, Amsterdam, North-Holland Publishing Co., 1954.

[19] LADD, GEORGE W., AND GEORGE R. WINTER, "Supply of Dairy Products by Iowa Farmers," *J. Farm Econ.* 43:113–122, Feb. 1961.

[20] MODIGLIANI, FRANCO, AND RICHARD SUTCH, "Innovations in Interest Rate Policy," *Am. Econ. Rev.* 56: 178–197, May 1966.

[21] NERLOVE, MARC, "Estimates of the Elasticities of Supply of Selected Agricultural Commodities," *J. Farm Econ.* 38:496–509, May 1956.

[22] ———, *Distributed Lags and Demand Analysis for Agricultural and Other Commodities*, Washington, USDA Agricultural Handbook 141, June 1958.

[23] SOLOW, ROBERT M., "On a Family of Lag Distributions," *Econometrica* 28:393–406, April 1960.

[24] WILSON, ROBERT R., AND RUSSELL G. THOMPSON, "Demand, Supply, and Price Relationships for the Dairy Sector, Post-World War II Period," *J. Farm Econ.* 49:360–371, May 1967.

[25] ZEPP, GLENN A., AND ROBERT H. MCALEXANDER, "Predicting Aggregate Milk Production: An Empirical Study," *Am. J. Agr. Econ.* 51:642–649, Aug. 1969.

An Open Econometric Model of the Canadian Beef Cattle Sector*

S. N. Kulshreshtha and A. G. Wilson

Limited information is available concerning the relationships existing among demand, supply, and price within the Canadian beef cattle sector. Since the sector is very dependent on exports to the U.S.A., an open econometric model is developed to estimate the simultaneous relationships prevailing among the demand, supply and price, and export variables. The two-stage least squares procedure is adopted to obtain a solution. It was estimated that by 1975 both Canadian domestic demand for beef and farm prices of beef will increase, but exports of live cattle will decline. The model also revealed that the price and production levels of feed grains are important factors in accommodating the expansion of demand.

The primary objective of this paper is to report on an econometric model of the Canadian cattle sector which includes the prevailing demand, supply, and price relationships. External trade is incorporated to provide an open model. This analysis of the Canadian cattle sector differs from earlier ones[1] in that an attempt is made here to estimate the simultaneous relationships existing among the demand, supply, price, and export variables.

Production of cattle and calves is an important agricultural activity in all regions of Canada.[2] Receipts from sales of cattle and calves have constituted about 21.75 percent of total annual farm cash receipts in recent years—about $936 million.[3] Beef and veal occupy an important position in the consumer's food basket, comprising approximately 11 percent of the total consumer food purchase.[4] The contribution of cattle and calves to the total earnings of foreign exchange is also impressive. Between 1965 and 1969 exports of these products averaged $79.16 million annually, representing about 5.2 percent of the total value of agricultural exports.[5] The Canadian cattle sector is therefore profoundly influenced by factors outside the domestic economy.

The Model

Equations contained in the model are presented below. Endogenous variables are identified by asterisks (*). The subscript t refers to a particular time period ($t=1$ for 1949, . . . , 21 for 1969).

(1) *Domestic demand for beef*[6]

$$DDB_t^* : RPB_t^*, PDI_t, PPK_t$$

(2) *Export demand for live cattle*

$$EXC_t^* : FPB_t^*, PDIF_t, SPB_t^*, DUM_t, TIME$$

(3) *Total demand for finished beef*

$$TDM_t^* = (DDB_t^*)(POPN_t) + NEXB_t$$

(4) *Retail price of beef*

$$RPB_t^* : DDB_t^*, FPB_t^*, MGNB_t, DUM_t$$

(5) *Total supply of finished beef*

$$SUPB_t^* = (ISLB_t^*)(WTB_t^*) + UISB_t$$

* Very valuable comments concerning this paper were received from Drs. P. J. Thair, G. G. Storey, and R. C. Nicholson of the University of Saskatchewan and from three reviewers. This paper is based on a revised version of the model developed by D. N. Brown [1] as a M.Sc. thesis submitted to the University of Saskatchewan, 1970.

[1] The main emphasis in these studies has been to examine either demand, supply, or cattle cycles. For more details of these studies see Yeh [12], Yankowsky [11], and Holmes [4] for demand; Kerr [5] and Lohoar [8] for supply; and Marshall [9] for cattle cycles.

[2] This sector is very important at present in the provinces of Quebec, Ontario, and Alberta. With the prospect of a relative decline in Canadian grain production, its importance in other provinces is likely to increase.

[3] This estimate is an average for the period 1965–69. Since 1945 contributions of the cattle and calves sectors have increased from 16.8 percent during 1946–50 to 21.5 at present. Data are obtained from Dominion Bureau of Statistics (D.B.S.), *Handbook of Agricultural Statistics, Part II, Farm Income.*

[4] Data obtained from D.B.S., *Urban Family Expenditure Surveys*, 1962.

[5] Based on data obtained from Canada Department of Agriculture, *Livestock Market Review*, and D.B.S., *Exports of Canada.* It includes the value of exports of live cattle as well as those of beef and veal.

[6] The variables to the left of colon should be read as being dependent upon those appearing to the right. For example, equation (1) can be rewritten as

$$(1.1)\quad DDB_t^* = \psi(RPB_t^*, PDI_t, PPK_t)$$

S. N. Kulshreshtha *is assistant professor of agricultural economics at the University of Saskatchewan.* A. G. Wilson *is research economist with the Canada Grains Council, previously associate professor of agricultural economics at the University of Saskatchewan.*

(6) *Inspected slaughter of beef cattle*

$$ISLB_t^* : INVB_t^*$$

(7) *Dressed weight per head*

$$WTB_t^* : INVB_t^*, TIME, \left(\frac{FPB}{PFG}\right)_t, FGS_{t-1}$$

(8) *Beef cattle inventory*

$$INVB_t^* : EXC_t^*, IVHS_t, FGS_{t-1}, EXPB_t, \left(\frac{FPB}{PFG}\right)_t, ISLB_{t-1}$$

(9) *Demand supply balance*

$$TDM_t^* = SUPB_t^* + \Delta ST_t$$

where

DDB_t^* = Apparent per capita domestic disappearance of beef in pounds, a measure of per capita consumption,

RPB_t^* = Deflated retail price of beef (selected cuts) in cents per pound,

EXC_t^* = Number of live feeder cattle exported from Canada, in thousands of head,

FPB_t^* = Deflated farm price (average for all markets) of beef cattle in dollars per hundredweight,

TDM_t^* = Total demand for beef in thousands of pounds,

$SUPB_t^*$ = Total domestic supply of beef (cold dressed carcass weight equivalent) in thousands of pounds,

$ISLB_t^*$ = Number of beef cattle slaughtered under federal inspection,

WTB_t^* = Average cold dressed carcass weight per head in pounds,

$INVB_t^*$ = Number of beef cattle on farms at beginning of the year (recorded as of December 1 in previous year) in thousands of head,

PDI_t = Deflated per capita personal disposable income in dollars,

PPK_t = Deflated retail price index of pork (1961 = 100) used as a measure of the influence of substitute meats,

$PDIF_t$ = Price difference between Omaha and Winnipeg for feeder steers adjusted for tariffs, exchange rates, and transport charges in dollars per hundredweight,

SPB_t^u = Per capita supply of beef in U.S.A. in pounds,

DUM_t = Dummy variable—1 assigned to the year 1952–56, 0 to the remaining years,

$POPN_t$ = Population of Canada in thousands of persons,

$NEXB_t$ = Net exports of finished beef in thousands of pounds,

$MGNB_t$ = Deflated wage rate in the meat processing industry in dollars per hour,

$UISB_t$ = Estimated total weight (basis cold dressed carcass) of uninspected cattle slaughter in pounds,

$\left(\frac{FPB}{PFG}\right)_t$ = Ratio of farm price of beef cattle to the index of the price of feed grains (subsequently referred to as the beef grain index),

$EXPB_t$ = Farm price of beef cattle deflated by the feed grain price index average for the period $(t-3)$ to $(t-5)$,

$TIME$ = Trend variable, (1959 = 1, · · · 1969 = 21),

FGS_t = Net feed grain supply per animal unit in tons,

$IVHS_{t-1}$ = Average number of beef heifers and steers in the year $(t-1)$, plus average number of calves in the year $(t-2)$, in thousands of head,

$ISLB_{t-1}$ = Lagged total slaughter of cattle in thousands of head,

ΔST_t = Change in storage stocks of beef (beginning less end of year) in thousands of pounds.

Specific Considerations in the Model

In equation (1) variations in per capita consumption are postulated to be accounted for by changes in the retail price, the price index of substitute meats,[7] and the deflated personal disposable income (per capita) of consumers. The variable PPK_t was considered an exog-

[7] In an alternative formulation, this price index included the prices of both pork and poultry meats. However, due to a declining trend in the price of poultry meats, a negative (and therefore inconsistent) sign for the cross elasticity resulted. This index was therefore reconstructed using pork prices only.

enous variable for the beef economy, although from the standpoint of the entire livestock economy it may become endogenous. Since the examination of the pork economy is left to broader investigation, treatment of PPK_t as an exogenous variable is justified.

The export demand for live cattle, as expressed by equation (2), is thought to be influenced by the farm price of beef cattle in Canada, by the price differential (adjusted for exchange rates and tariff rates)[8] between Canadian and U. S. markets,[9] and by the per capita supply of beef in the United States.[10] However, in initially solving this equation it was discovered that the level of exports was minimal during 1952–56 as a result of the foot and mouth disease outbreak in 1952. The impact of this outbreak is taken into account by introducing a dummy variable and a time trend variable into the equation.

Equation (3) describes an identity: total demand for finished beef being equated to net exports plus the product of per capita consumption of beef and population.

The retail price for beef, equation (4), reflects the relationship between retail and farm prices. In addition to the respective prices, per capita consumption, an index of the wage rates in the meat processing industries, and a dummy variable are incorporated into the equation. The wage index is taken as being a proxy for the marketing margin, or in other words, the farm to retail price spread. The purpose of the dummy variable is to take into account the reduced level of exports caused by the outbreak of foot and mouth disease.

Equations (5) through (8) describe the supply situation prevailing in the beef sector. Equation (5) expresses the total supply of beef as an identity. Supply is considered equivalent to the weight of the beef which arises from inspected slaughter plus that which arises from uninspected slaughter. The former is treated as the product of the number of cattle slaughtered under federal inspection and the average cold dressed carcass weight.

The number of cattle slaughtered under federal inspection was explained, in an earlier version of equation (6), by the farm price of beef cattle and the beef cattle inventory at the beginning of the year,[11] the farm price of milk, and the expected price of beef cattle. The expected price of beef cattle is an average ratio of the beef prices deflated by feed grain price index for the year $t-3$ to $t-5$.[12] The initial solution to this equation indicated that inclusion of any variable other than the current beef cattle inventory would not result in a significant improvement in the coefficient of determination. Consequently, cattle slaughter in this equation is determined only by the current level of inventory.

The dressed weight per animal is influenced, as shown in equation (7), by the farm price of beef cattle, the beginning inventory, the expected price of beef cattle, and the net supply of feed grains per animal unit in the year $t-1$.

The beef cattle inventory, which is used as a variable to explain the supply of beef in the two previous equations, is in turn explained in equation (8). Variations in the inventory are related to those occurring in the number of feeder cattle exported, the farm price of beef cattle, the expected price of beef cattle, the number of heifers, steers, and calves in the previous years, and the net feed grain supply in the previous year.

The final equation (9) is an identity in which the total domestic supply of finished beef is balanced with total domestic and export demand and the net change in storage stocks.

In this model the scope for interaction between the beef cattle and the other livestock sectors was limited. A comprehensive study of the entire livestock economy is now underway in an attempt to overcome these shortcomings.

Results of the Analysis

Annual data covering 1949–1969 were used in estimating the parameters. The following estimates of the parameters of the various equations were obtained by using the two-stage least squares regression procedure:

[8] It was considered that if the price in a Canadian market were low enough to allow an American entrepreneur to buy the cattle in U. S. dollars, pay the tariff and transportation costs, and make a profit, cattle would flow to the United States.

[9] The markets considered were Omaha and Winnipeg. The prices represent those of feeder steers.

[10] This variable was included as an indicator of the pull-factor on Canadian exports. If per capita supply declines in the United States, it is expected that more imports from Canada will be required to supplement the local supply.

[11] The beginning inventory is that reported by D.B.S. on December 1. Therefore, the inventory on December 1 of the year $t-1$ was taken as the value of the beginning of year inventory variable for the year t.

[12] The choice of the period $t-3$ to $t-5$ was based on the length of the gestation period in beef production.

Demand for beef[13]

$$DDB_t^* = 49.579 - \underset{(0.070)}{0.554}\, RPB_t^* + \underset{(0.0024)}{0.0503}\, PDI_t + \underset{(0.0799)}{0.0374}\, PPK_t \tag{10}$$

$$R^2 = 0.9613 \qquad d = 2.016$$

Export demand for live cattle

$$\begin{aligned} EXC_t^* = {} & 495.96 - \underset{(26.392)}{23.637}\, FPB_t^* + \underset{(17.564)}{26.128}\, PDIF_t + \underset{(6.185)}{1.964}\, SPB_t^u - \underset{(71.03)}{329.39}\, DUM_t \\ & - \underset{(11.725)}{19.219}\, TIME \end{aligned} \tag{11}$$

$$R^2 = 0.6503 \qquad d = 2.536$$

Retail price of beef

$$RPB_t^* = 30.330 - \underset{(0.3020)}{0.1769}\, DDB_t^* + \underset{(1.229)}{4.968}\, FPB_t^* + \underset{(9.149)}{26.2681}\, MGNB_t - \underset{(2.812)}{1.2509}\, DUM_t \tag{12}$$

$$R^2 = 0.7805 \qquad d = 2.341$$

Inspected slaughter of beef cattle

$$ISLB_t^* = 275539 + \underset{(26.35)}{477.376}\, INVB_t^* \tag{13}$$

$$R^2 = 0.9453 \qquad d = 1.878$$

Dressed weight per head

$$WTB_t^* = 470.787 - \underset{(0.007)}{0.0205}\, INVB_t^* + \underset{(1.352)}{6.667}\, TIME + \underset{(1.491)}{2.015}\left(\frac{FPB}{PFG}\right)_t + \underset{(8.834)}{20.833}\, FGS_{t-1} \tag{14}$$

$$R^2 = 0.9624 \qquad d = 1.425$$

Beef cattle inventory

$$\begin{aligned} INVB_t^* = {} & -1764.85 - \underset{(0.189)}{0.0779}\, EXC_t^* + \underset{(0.163)}{1.265}\, IVHS_t + \underset{(300.58)}{795.56}\, FGS_{t-1} + \underset{(64.64)}{95.97}\, EXPB_t \\ & - \underset{(39.94)}{40.51}\left(\frac{FPB}{PFG}\right)_t - \underset{(0.281)}{0.494}\, ISLB_{t-1} \end{aligned} \tag{15}$$

$$R^2 = 0.9823 \qquad d = 1.725$$

Interpretation

The demand for beef at the retail level was found to be positively related to consumer incomes and the price of pork and negatively to its own price. Among these variables the retail price had the greatest impact.

The difference between the Omaha and Winnipeg prices was positively but weakly related to the export demand for live cattle. A dummy variable, introduced to account for the disturbance in trade caused by the foot and mouth outbreak, was very strongly and negatively related to exports. The farm price of beef cattle in Canada was also found to be negatively related to the level of exports. The

[13] The figures in the parentheses are standard errors of the β values. Since the standard errors of two-stage least squares have an asymptotic distribution, a t value of 1 or more may be considered significant. For details see Langemeier and Thompson [7, p. 174]. The d statistics, though presented, are of questionable value for equations in a simultaneous system.

interpretation which may be given to this situation as indicated by the negative coefficient is that a high level of exports is possible only when Canadian prices are low.

The retail price of beef was positively related to the farm price of beef cattle and the index of marketing charges and negatively related to per capita demand and the dummy variable. Signs of the regression coefficients were logically consistent.

Variations in the inspected slaughter of beef cattle were explained solely by variations in the beginning inventory to which they were positively related.

The dressed carcass weight of beef cattle (on a per-head basis) was strongly and positively related to time and the feed grains supply per animal in the previous period. The inventory of cattle was significantly and negatively related to dressed weight, indicative of adjustments in herd size and the weight to which the animals were fed.

The beef cattle inventory was positively and strongly related to the number of heifers, steers, and calves in the previous years and to the feed grain supply. On the other hand, the volume of cattle exports, beef grain index, and lagged slaughter were found to be negatively (but weakly) related to the inventory. A higher value of any one of these three variables would have a depressing effect on inventory.

Elasticities of Demand and Supply

To measure the responsiveness of demand and supply, price, and other relevant elasticities were calculated. According to these estimates, the price elasticity of beef is −0.801, and the cross elasticity of demand for beef with respect to the price of pork is 0.055. The income elasticity of beef was 1.044, suggesting that an increase in per capita income will be accompanied by a somewhat larger proportional increase in per capita consumption. The magnitude of these elasticities, when compared with those reported by other Canadian studies, is slightly greater since fewer variables were incorporated into the model.[14]

The price elasticity of demand was also calculated at the farm level.[15] It was estimated at −0.3072, indicating that demand at the farm level is more inelastic with respect to price than at the retail level.

The elasticity of exports with respect to farm price was −0.8071, indicating that variability in the level of exports is closely associated with price changes at the farm level. In contrast, elasticity of exports with respect to the price differential was estimated as only 0.0336.

On the supply side, the price of beef cattle was introduced at two levels: (1) the feeding process, decision-making level (dressed weight per head) and (2) the inventory level. Elasticities were calculated with respect to the current beef-grain index and the expected level of beef prices (that is, the deflated average price over the $t-3$ and $t-5$ period). The elasticity of supply (dressed weight per head) with respect to the beef-grain index was 0.034, indicating a minimal response in cattle feeding to changes in the farm price level relative to feed grain prices. The elasticity of supply (inventory) with respect to the beef-grain index was −0.098. In other words, grain prices had a negative yet minimal effect on inventory. In contrast, the responsiveness of inventory with respect to the expected price of beef cattle was slightly greater in absolute terms than that of the beef-grain index, the elasticity of supply with respect to the expected price being 0.2149. These results approximate those obtained by Langemeier and Thompson [7, p. 178] for the U.S. beef economy.

Canadian Beef Economy in 1975

One of the major uses for a model of this nature is predicting changes in the beef cattle sector on the basis of certain projections with respect to the levels of the exogeneous variables. The prediction efficiency of each equation was tested using Theil's U-coefficient procedure.[16] The respective coefficients are shown in Table 1. If the U-coefficient is equal to 0, the forecasts are perfect. When $U=1$, there is a complete lack of relationship between the predicted and actual values. Coefficients with the

[14] The demand equation contained relatively few variables giving rise to elasticities slightly higher than those reported elsewhere. Yeh [12] reported a price elasticity of −0.644 and an income elasticity of 0.39.

[15] These estimates were made by solving the demand and price structure equations in terms of demand as a function of the farm price and then applying the appropriate means.

[16] The coefficient can be written as

$$U = \sqrt{\frac{\Sigma(P_i - A_i)^2}{n}} \Big/ \sqrt{\frac{\Sigma(A_i)^2}{n}} + \sqrt{\frac{\Sigma(P_i)^2}{n}}$$

where

P_i = predicted value
A_i = actual value
n = number of observations.

Table 1. Theil's U-coefficient for various equations

Equation number	Endogenous variable	Theil's U-coefficient
10	Per capita demand	0.01500
11	Exports of live cattle	0.15660
12	Deflated retail price of cattle	0.01752
13	Inspected cattle slaughter	0.01437
14	Dressed weight per head	0.00445
15	Cattle inventory	0.01864

exception of those pertaining to exports of live cattle were very close to zero, indicating the equations may be used to predict changes with a reasonable degree of confidence.

To make forecasts, the system of estimated equations plus identities was converted into a reduced form system. The prediction of exogenous variables for 1975 was made using an autoregressive equation. For those variables in non-linear or non-additive form,[17] linear approximations were made using the method suggested by Klein [6, pp. 120–121]. A projection of the Canadian beef cattle sector for 1975 is based on this methodology. Data used in this prediction are provided in Appendix B.

Results of the projection are shown in Table 2 along with the respective 1965–69 averages. According to these estimates, per capita domestic consumption of beef will increase to 95.75 lbs., an increase of 12.6 percent over the 1965–69 average level. If this increase is multiplied by that of the population, the estimated total consumption in 1975 will be 30.6 percent above the actual annual average for the 1965–69 period. Similarly, the deflated retail price for beef is expected to increase by 7.4 points, or to 115.5 in 1975. Exports of live cattle, unless the American price for feeder cattle increases significantly, are expected to decline from the average 1964–69 level by about 16 percent. Changes in the consumption sector will be consistent with the supply of beef. Consequently, substantial increases are indicated. It is predicted that inspected slaughter will increase 24 percent, carcass weight per head 8.5 percent, and the beef cattle inventory 29 percent over the 1965–69 average.

Changes in the per capita consumption of beef, retail price index of beef (deflated), level of inspected slaughter for beef cattle, and dressed weight per head are plotted in Figure 1. These projections are based on a simultaneous change in the exogeneous variables taken together and therefore reflect the mutual interdependencies existing in the Canadian cattle sector.

Conclusions

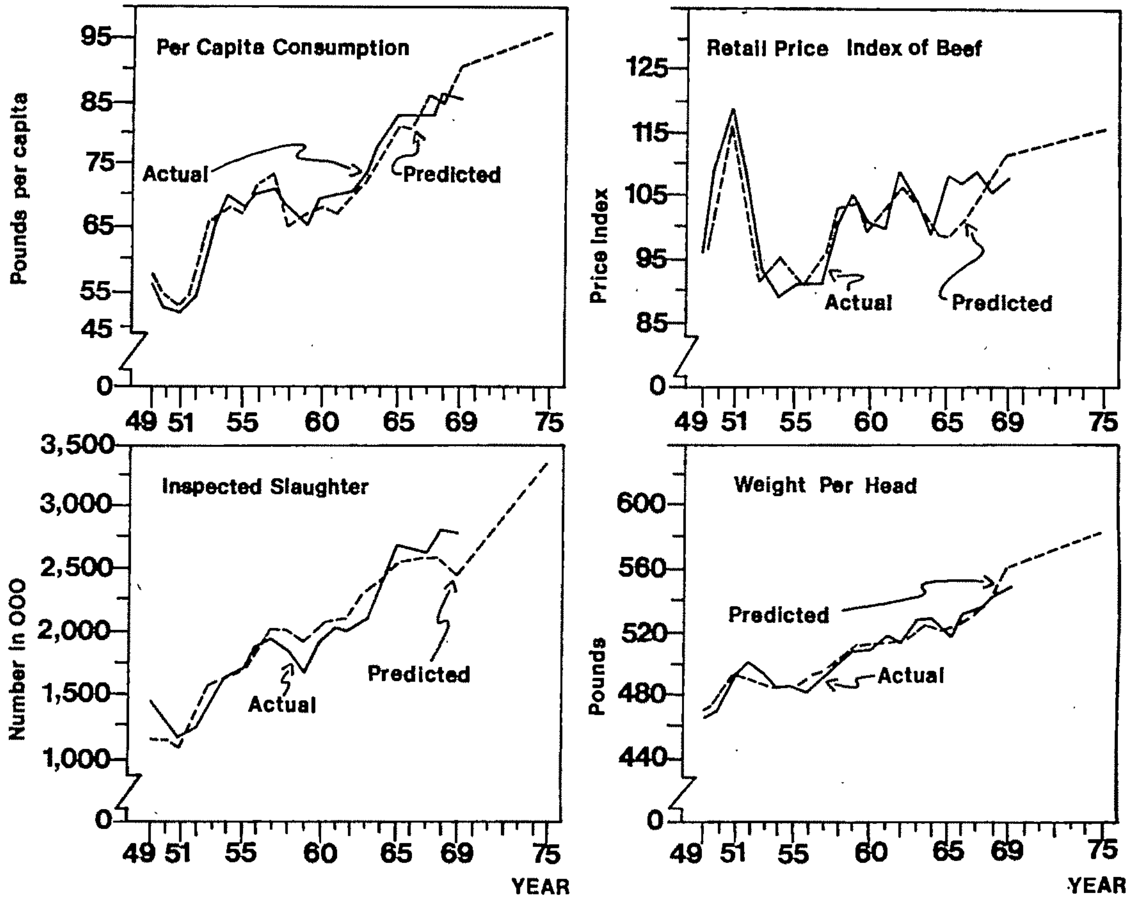
The model of the Canadian beef cattle sector used in this study provides an insight into procedures that may be used to improve its economic health. Knowledge of this type is particularly valuable in this period of agricultural adjustment.

Canadian policy makers have been encouraging a switch from grain to livestock production on many prairie farms. This study indicates that, if the production of beef is to be increased in the short run, a high beef feed index is required. However, in the long run increased output of beef depends on an abundant supply of feed grains. If a keen export demand arises for feed grains as a result of adverse production conditions in other areas, the incidence of corn blight in the United States being a good example, beef output will decline in both the short

[17] These transformations were required for variables such as DDB_t^* and $(FPB/PFG)_t$ in equations (1) and (7) and for $(ISLB_t^*)$ (WTB_t^*) in equation (5).

Table 2. Predicted values of the endogenous variables for the Canadian cattle economy, 1975, and annual average, 1965–69

Variable	Unit	Value 1965–69 average	Value 1975	Percent increase (+) or decrease (−) from 1965–69
Total domestic demand for meat	million pounds	1,728.00	2,258.00	+30.6
Per capita consumption	pounds	84.98	95.75	+12.6
Deflated retail price index for beef	1961=100	107.48	115.47	+ 7.4
Exports of live cattle	thousand head	214.95	179.51	−16.5
Farm price of beef cattle non-deflated	dollars per hundredweight	22.67	31.70	+39.8
Level of inspected slaughter	thousand head	2,716.87	3,377.66	+24.3
Carcass weight per head	pounds	538.34	584.40	+ 8.5
Inventory of beef cattle, beginning of year	thousand head	4,865.58	6,284.63	+29.2



Canadian Beef Economy, 1949–1975
Figure 1. Actual and predicted value of selected endogenous variables

and long run. The demand for beef is profoundly influenced by domestic per capita income. A positive program to increase the output of feed grains combined with a general policy to encourage growth and development in the economy will be required if production expansion policies are to be attained. Increases in the output of beef also appear dependent on a positive price differential between American and Canadian markets.

References

[1] BROWN, D. N., *An Econometric Analysis of the Canadian Cattle-Calves Economy*, unpublished M.S. thesis, University of Saskatchewan, 1970.

[2] EGBERT, ALVIN C., AND S. REUTLINGER, "A Dynamic Long-Run Model of the Livestock-Feed Sector," *J. Farm Econ.* 47:1288–1305, Dec. 1965.

[3] GOLDBERGER, ARTHUR S., *Econometric Theory*, New York, John Wiley & Sons, 1964.

[4] HOLMES, R. A., *The Estimation of Demand Elasticities for Substitute Food Products*, Agr. Econ. Res. Coun. of Canada Pub. 13, 1966.

[5] KERR, T. C., *Determinants of Regional Livestock Supply in Canada*, Agr. Econ. Res. Coun. of Canada Pub. 15, 1968.

[6] KLEIN, LAWRENCE R., *A Textbook of Econometrics*, Evanston, Ill., Row, Peterson, and Co., 1953.

[7] LANGEMEIER, LARRY, AND RUSSELL G. THOMPSON, "Demand, Supply and Price Relationships for the Beef Sector, Post-World War II Period," *J. Farm Econ.* 49:169–183, Feb. 1967.

[8] LOHOAR, J. S., "Prospects for Increasing Beef Supplies in Canada," *Canadian Farm Econ.* 4:1–8, April 1969.

[9] MARSHALL, R. G., *Variations in Canadian Cattle Inventories and Marketing*, Guelph, Dept. of Agr. Econ. Pub., 1964.

[10] WALLACE, THOMAS D., AND GEORGE G. JUDGE, *Econometric Analysis of the Beef and Pork Sectors of the*

Economy, Okla. Agr. Exp. Sta. Tech. Bull. T-75, Aug. 1958.

[11] YANKOWSKY, Z. J., AND F. SHEFRIN, *Demand-Supply Projections for Canadian Agriculture—1980*, Canada Dept. of Agr., Econ. Branch, Ottawa, 1968.

[12] YEH, M. H., "Consumer Demand for Beef and Pork in Canada," *Canadian J. Agr. Econ.* 9:68–78, 1961.

APPENDIX A

Sources of Data

The model required data for seven endogenous and 16 exogenous variables. Data on consumption and prices were assembled from the following D.B.S. publications: *Price and Price Indexes* (62-002) and *Livestock and Animal Product Statistics* (23-203). Data required for the exogenous and the other endogenous variables were taken from D.B.S., *Quarterly Bulletin of Agricultural Statistics;* Canada Department of Agriculture, *Livestock Market Review;* and D.B.S., *Review of Man Hours and Hourly Earnings.* Data on the price of feeder cattle in Omaha were obtained from unpublished sources.

APPENDIX B

Values of Exogenous Variables Used for the Projection of Beef Cattle Sector, 1975

Variable		Value	Variable		Value
PDI_t	dollars	2,255.87	$UISB_t$	pounds	338,823.00
PPK_t		105.20	$EXPB_t$	dollars	12.44
$PDIF_t$	dollars	0.50	$TIME$	years	27.00
SPB_t^u	pounds	118.50	FGS_t	tons	1.35
DUM_t		0	$IVHS_{t-1}$	thousand head	6,608.20
$POPN_t$	thousands	23,582.00	$ISLB_{t-1}$	thousand head	3,960.00
$NEXB_t$	million pounds	5,721.00	ΔST_t	thousand pounds	−903.00
$MGNB_t$	dollars per hour	2.66	Ratio of farm price received index to feed grain price index		1.75

A General Model for Evaluating Agricultural Flood Plains*

RONALD D. LACEWELL AND VERNON R. EIDMAN

An important part of agricultural flood plain development is providing flood protection. However, planning procedures have been criticized for (1) considering only flood protection methods as means of coping with flood losses, (2) developing inequitable land owner assessments following installation of a protection project, and (3) inadequately anticipating land use adjustments and their effect on project benefits. The model discussed in this paper can be used to estimate the incidence of agricultural flood damages and avoid the above criticisms. The model can be used to evaluate alternative protection plans, estimate flood insurance premiums, equitably allocate assessments, and select improved land use patterns.

AN EVALUATION of potential development of agricultural flood plains should consider, conjunctively, alternative uses for the land and alternative methods of coping with flood losses. Evaluations are frequently made for a single flood protection plan and a single land use pattern. The general public, flood plain users, and some planning agencies frequently consider the use of flood detention structures and levees as the only means of controlling mounting flood losses [11, p. 11]. However, zoning restrictions, insurance, educational programs for flood plain land owners, and combinations of these should also be considered in planning the development of agricultural flood plain land.

Reliable flood damage estimates are necessary for efficient flood plain planning. Procedures for estimating flood losses have been formulated by governmental agencies and are particularly useful in estimating flood losses for relatively large areas such as an evaluation reach.[1] Damage estimates are typically based on a composite acre for the evaluation reach.[2] Basing estimates on the composite acre precludes estimating losses for areas smaller than the evaluation reach because land use at any given location is unspecified. Criticism of present estimating procedures is not directed toward the accuracy for relatively large areas, bu toward the inaccuracy and difficulty of obtaining flood damage estimates for relatively small areas such as a particular field. Evaluations that consider both alternative land use and alternative methods of coping with the losses require the estimated incidence of flood losses by location in the flood plain.

This article discusses a model that may be used to estimate flood damages by small tract for flood plains devoted to agricultural uses. An application of the model to a small watershed in eastern Oklahoma illustrates that the disaggregated damage estimates can be used to establish (1) more equitable assessments of the local costs of flood protection, (2) annual premiums for flood insurance, and (3) cropping patterns having the greatest returns.

Methodology[3]

The model integrates some procedures presently used in estimating agricultural flood damages with some new techniques. The model uses the basic mechanics of the frequency method of flood damage estimation. However, computation of flood damages is based on a point sample method rather than the presently used composite acre [1]. The model uses a uniform assignment of sample points throughout the flood plain with each sample point representing a specified number of flood plain acres. The model computes flood damages for each sample point, with the damages based on unique characteristics of the point (land use,

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[1] An evaluation reach typically includes flood plain land on both sides of the channel and one or more cross sections. The cross sections are frequently more than 3,000 feet apart.

[2] A hypothetical acre composed of the proportion of each land use in the evaluation reach.

[3] A more complete and detailed discussion of the methodology including a mathematical definition of the model is presented in a forthcoming Oklahoma Agricultural Experiment Station publication.

RONALD D. LACEWELL *is assistant professor of agricultural economics at Texas A&M University.* VERNON R. EIDMAN *is professor of agricultural economics at Oklahoma State University.*

location, soil productivity, and depth of inundation).

The computational procedure uses data presently available in flood damage studies, i.e., crop damage factors, cross section data, and hydrology, through which flood elevation data are determined. Crop damage factors, typically utilized in discrete form, are converted to continuous functions, thus increasing the sensitivity of flood damages to depth of inundation.

The model is composed of a series of computational steps for each sample point in the portion of the flood plain under study. The sequential steps for a sample point are (1) calculate elevation, (2) calculate depth of inundation for specified flood sizes, (3) weight damage factors by seasonal probability of flooding and convert to a continuous function of inundation depth, (4) calculate flood damages, (5) determine proportion of potential gross revenue lost to flooding, and (6) calculate returns net of production costs and average annual flood damages. A modification of the model adds a seventh step to determine the land use that maximizes returns net of production costs and average annual flood damages for the sample point. The input data required, type of computational procedures and results obtained for each step or segment of the model are presented below.

Sample point elevation

The first segment estimates the elevation of each sample point by relating the sample point to the appropriate cross section. Input data utilized are measured land elevations at stations across the channel (cross section stations), feet between stations, total stations on each channel side, and sample point location.[4]

The procedure determines where the sample point would lie if it were located on the cross section. The elevation of the cross section at that point is assigned to the sample point. The elevation of a sample point falling between two stations on a cross section is calculated by using the elevation of the nearest station on each side of the sample point and linear interpolation procedures.

Depth of inundation

The frequency method of computing flood damages requires selecting a series of discrete storm (flood) sizes to represent the distribution of floods in the watershed. Hydrologists typically select the storm sizes and calculate peak flood evaluations throughout the watershed for each storm size. The second segment of the model uses this information to determine the depth of inundation at each sample point for each flood size.

Depth of inundation for flood size k equals the peak elevation of the flood minus the sample point land elevation computed in the previous step. Each sample point has a depth of inundation associated with each of the flood sizes. A negative inundation depth for a specific flood size indicates that the land elevation of the sample point exceeds that of the flood and, hence, no flooding occurs.

Damage factors

Damage factors used in current methods of estimating flood losses represent the percent reduction in expected gross returns by crop and season for an increment of inundation, such as inundation from 0 to 1 foot, 1 foot to 3 feet, and 3 feet or more.[5] These factors are used as input data by the model but are weighted by the seasonal probability of flooding to allocate the flood over all seasons and prevent overestimating flood damages.

The model converts these weighted damage factors for the jth discrete inundation increment to a linear function of inundation depth. To convert from a single damage factor for an inundation depth increment to a functional relationship between damage factors and inundation depth, the weighted damage factor for an inundation increment is assumed to be the factor for the midpoint of that increment and is assigned to the median depth of inundation for the increment. Using these midpoints as boundaries of redefined inundation intervals and connecting the plotted values with straight-line segments, a unique damage factor for each

[4] The location of a sample point is designated by channel side and the point's distance from the channel expressed as a proportion of the distance from the channel to the flood plain boundary.

[5] The USDA's Soil Conservation Service estimates seasonal damage factors for individual crops or groups of crops based on flood occurrence and experiments. The variable considered most important in accounting for the amount of loss on a given crop in a specified season is depth of inundation. Thus, damage factors are estimated for several depth of inundation intervals. However, these damage factors are somewhat inaccurate because other variables such as duration of inundation, flood velocity, and sediment deposition also affect the extent of flood damages incurred. Development of damage factors as a function of several of these variables appears to be a useful approach to reducing errors in estimating flood losses.

depth of inundation is obtained. For the last inundation depth increment (such as 3 feet or more) the damage factor reaches a maximum and remains constant over the increment.

Calculating flood damages

The fourth segment of the model utilizes these crop damage factors to compute average annual damages by flood size for each sample point. The expected damage per acre from flood k is the sum of the gross value, assuming no flooding occurs, multiplied by the weighted damage factor for each season. The resulting value applies to a given flood size k and land use at sample point r and makes no specification as to the season in which the flood occurred. The relationship weights damages that would result in each season from flood size k by seasonal probability of flooding. Summing the weighted seasonal damage estimates gives estimated damages per acre from flood size k.

Expected damages per acre are computed for each of the several flood sizes selected to represent the distribution of storms in the watershed. Damage estimates for each flood size are used to estimate average annual flood damages on the acres represented by a sample point.

Hydrologists specify the frequency of occurrence for each of the k flood sizes. The probability of each flood occurring in a given year is obtained by simply dividing the number one by the frequency of the flood in years. Multiplying the damage expected in the year each flood occurs by the flood's probability of occurrence in any given year results in the expected damages per acre for flood size k in any given year. Average annual damages on the acres represented by a sample point are the summation of the expected damages for each flood in any given year multiplied by the acres each sample point represents.

Average annual damages can be determined for any combination of R sample points (such as one field or one farm) by summing average annual damages for each sample point included in the delineated area. The summation of the average annual flood damages for all sample points representing any portion of the flood plain—whether it is one field, one farm or a group of farms—results in total expected average annual damages for that area.

Proportion of gross value lost to flooding

The fifth segment of the model computes average annual flood damages as a percent of gross revenue of production with no flooding. This is accomplished by simply dividing average annual damages by gross returns with no flooding.

Net returns considering flooding

The sixth and final segment of the model subtracts from gross returns, by sample point, the production costs and average annual flood damages. This provides an estimate of sample point net returns considering expected losses due to flooding.

Optimization routine

The optimization routine computes the returns net of production costs and average annual flood damages for each alternative land use (crop) at a sample point and selects the land use having the greatest expected net returns. This modification permits one to estimate the optimum cropping pattern for the flood plain including the associated net returns and flood damages. Selecting the optimum cropping pattern with no structures and with each of several systems of detention structures provides planners with much information on the available alternatives for the watershed.

This routine selects the optimum land use at a sample point for a given set of prices. The procedure also identifies the second most profitable land use.[6] This information is used to determine the product price for the optimum land use on a sample point that will result in a net return value equal to the second best land use. This provides an indication of the stability of the solution at each sample point.

The modification in the general model provides, by sample point, estimates of (1) average annual flood damages of each crop considered in the flood plain, (2) gross returns with no flooding for all considered crops, and (3) net returns considering flooding for all crops. Data calculated by the model and accumulated over the flood plain for optimum and second best land use, respectively, include (1) acreage of each crop with optimum and second best land use, (2) gross returns with no flooding, (3) expected net returns considering flooding, (4) production costs, and (5) average annual flood damages.

Data Requirements

The model outlined above utilizes much of the same information on crop damage factors,

[6] Second best land use at a sample point refers to the land use that produces the second largest returns net of production costs and average annual flood damages.

cross section elevation data, and hydrology that is normally developed for other flood damage studies. The input data requirements of the model can be separated into three classifications. The first classification is data applicable to the flood plain as a whole or the aggregate flood plain and includes statistics on historical flooding, specific flood sizes used in the analysis, crop damage factors, and crop characteristics (yield, price per unit, and production costs) by designated soil productivity groups.

The second classification refers to data required for the part of a flood plain represented by a specific cross section. Input data include elevations of the flood plain at each station on a cross section and the elevation at each cross section for each flood size considered in the analysis.

The last classification refers to sample point data and includes land use, location in the flood plain, and soil productivity group. The productivity groups for a flood plain may be designated by combining soil types having similar physical characteristics (texture, slope, depth of topsoil, permeability, and water-holding capacity) resulting in a similar yield response to variable inputs (seeding rate, fertilizer levels, irrigation water, pesticides, and cultural practices). Thus, soils within a productivity group have about the same gross returns, cash production costs, and net returns per acre for a given crop. If either the yields or the variable production expenses differ by crop for two soils, they should be placed in separate productivity groups. Defining the productivity group of a sample point requires identifying the soil type and determining which productivity group includes the soil.

As the above discussion indicates, large numbers of computations are required to estimate flood damages and select the profit-maximizing land use at each sample point throughout the flood plain. The majority of computations are repeated for each set of detention structures considered. A computer program was developed at Oklahoma State University in cooperation with the Economic Research Service to apply this model to small watershed planning. The input and output formats are general so the model can be applied to a wide variety of watersheds without modification. This program has been used to evaluate a watershed in southeastern Oklahoma. Discussion of the results that follow illustrates how the model can be used to estimate land use adjustments, evaluate flood protection benefits, and develop assessment rates for the individual owners of flood plain land.

Application

The Nuyaka Creek flood plain in southeastern Oklahoma was selected as the study area for developing and applying the model. Selection was based on the availability of watershed planning information, the large number of crops adaptable to the area, and absence of levees, dikes, or other physical characteristics that would render the model unworkable. A Soil Conservation Service flood control watershed project for the study area had already been planned and approved by Congress for construction. Hence, much of the input data required was already available.[7] Present land use in the Nuyaka Creek flood plain is composed primarily of pasture, although several crops are adaptable to the soils and climate of the watershed [12].

The incidence of flood damages was estimated for the present land use (1968 land use) under present flood plain conditions (no protection) and assuming a system of flood control structures (with protection).[8] The land use that maximizes profit was also estimated with and without flood protection.

The basic data on cross section elevations, storm frequencies, and hydrology developed by the Soil Conservation Service in developing the flood protection plan were used in this analysis. Soil productivity groups were developed and the appropriate cost and return estimates for alternative crops taken from published research relating to the bottomland in the area [7]. The amortized value of land clearing and preparation for crop production ($7.72 per acre) was included as a cost for alternative crops for sample points currently in woodland pasture [10].

Eleven alternative crops are considered in the analysis. The alternate crops are not considered when present land use is specified but are important in determining the sample point optimum land use. Adjusted normalized prices which remove the influence of government price support programs [13, p. 4] are assumed.[9]

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[7] The cooperation of the Soil Conservation Service in various stages of this research is recognized and sincere appreciation expressed.

[8] The 1968 flood plain land use by sample point is considered to be present land use and serves as an illustration of flood plain utilization in the absence of flood protection.

[9] The crops and corresponding prices utilized in this study are (1) grain sorghum @$1.69 cwt., (2) corn @$1.05 bu., (3) soybeans @$2.45 bu., (4) wheat @$1.30 bu., (5)

Table 1. Optimum and second best land use with corresponding net returns and stability of the optimum crop for the area represented by each of five sample points, present flood plain conditions[a]

Sample Point (1)	Land use: Optimum[b] (2)	Net returns (3)	Second[c] best (4)	Net returns (5)	Optimum[d] solution stability (6)
		dollars		dollars	percent
1	Soybeans	173.03	Alfalfa	170.28	0.91
2	Soybeans	171.19	Alfalfa	168.60	0.87
3	Alfalfa	149.41	Soybeans	143.26	1.46
4	Soybeans	164.56	Alfalfa	163.65	0.31
5	Native pasture	18.42	Native hay	4.96	74.04

[a] Present flood plain conditions refer to no flood protection.
[b] Optimum land use is the sample point profit-maximizing land use.
[c] Second best land use is land use at each sample point with the second largest net return value.
[d] Solution stability is measured by the percentage price decline required to equate optimum land use net returns with second best land use net returns, i.e., percentage price decline that yields a condition of indifference between optimum and second best land use based on net returns.

These product prices were selected for illustrative purposes because they are typically used in project evaluations. However, the appropriate set of product prices must be selected on the basis of the type of benefits (local, regional, and national) to be estimated.[10]

Land use adjustment

The optimum land use and second best land use are selected by sample point.[11] The flood plain is composed of 748 sample points or 3,740 acres (since each sample point represents 5 acres). Optimum land use and second best land use with corresponding net returns are presented in Table 1 for five sample points of a cross section area located in the Nuyaka Creek flood plain.

Column 2, Table 1 lists the optimum land use (computed without flood protection) for each of the five sample points. Crops selected as optimum on one or more of the five sample points include soybeans, alfalfa, and native pasture. Net returns per sample point (5 acres) range from $18.42 on sample point 5 to $173.03 on sample point 1. The frequency of flooding and depth of inundation associated with sample point 5 result in the selection of native pasture, a crop with more tolerance to floodwater than the others, as the most profitable crop.

The second best land use provides an alternative to the profit-maximizing land use and is used to establish the stability of the optimum solution at each sample point. For example, on sample point 1, production of the second best crop, alfalfa, rather than soybeans, reduces net returns $2.75 (from $173.03 to $170.28); and on sample point 5, native hay in place of optimum native pasture reduces net returns from $18.42 to $4.96.

The stability of the optimum solution is measured by the percentage price decline required to equate optimum and second best land use net returns. The greater the percent price decline the greater the solution stability (column 6, Table 1). An optimum solution of soybeans or alfalfa is nullified by a very small percentage price decline; i.e., a soybean price decline of 0.91 percent equates soybean net returns with alfalfa net returns on sample point 1, and an alfalfa price decline of 1.46 percent equates alfalfa net returns with soybean net returns on sample point 3.

The flood plain farmer could select either the optimum or second best land use for sample points 1–4 and have very little effect on his expected net returns, i.e., the optimum solution is relatively instable. However, sample point 5 represents a relatively stable solution and the flood plain farmer experiences a significant reduction in net returns by selecting the second best land use.

The aggregate effect of land use adjustments on gross revenue, production costs, average annual flood damages, and net returns for the flood plain can also be evaluated. The dollar

oats @$0.60 bu., (6) barley @$0.85 bu., (7) bermuda grass pasture @$2.50 per animal unit month (AUM) [9, p. 21], (8) alfalfa @$22.00 ton, (9) native hay @$22.00 ton, (10) woodland pasture @$2.50 AUM [9, p. 21], and (11) native pasture @$2.50 AUM [9, p. 21].

[10] It is important to determine the type of benefits (local, regional, or national) to be estimated and to use a set of prices reflecting that level of benefits. The extent to which the adjusted normalized prices used in this study reflect national benefits has been debated in the literature. Readers interested in this issue are referred to Knetsch, *et al.* [4, p. 6] for a discussion of the considerations involved.

[11] Optimum land use is defined as the crop having the highest returns per acre net of specified production costs and average annual flood damages. The second best use has the next largest net return per acre. The optimum flood plain land use pattern for a farm may differ from the model optimum because the amounts of upland, labor, capital, and allotments available may also affect the intensity of bottomland use.

values are shown for the Nuyaka Creek flood plain for present land use, both with and without flood protection, in Table 2. Corresponding values are also presented for the optimum land use.

The present land use (1968 land use) is given in column 3 of Table 2. A total of 2,910 acres is in pasture, 325 acres are in soybeans or alfalfa, and the remaining acreage is in cotton, corn, small grains, bermuda grass, and native hay. Estimated gross revenue to the 3,740 acres of flood plain with the present land use pattern is $54,600. Without flood protection, average annual flood damages are $11,600 and specified production costs total $31,300, leaving an estimated $11,700 return to land, management, and risk—a net return of $3.12 per acre of flood plain.

The land use that maximizes returns net of production costs and average annual flood damages without flood protection (present flood plain conditions) is given in column 5 of Table 2. Substantial shifts in acreage from pasture and small grains to soybeans and alfalfa are indicated. The optimum land use includes 2,495 acres of soybeans and alfalfa with only 1,055 acres of pasture.

A change of flood plain use from present to the optimum, with no flood protection, quadruples gross returns and increases net returns sevenfold (from $11,700 to $80,700). However, associated with the increase in net revenue (from $3.12 to $21.57 per acre) is a substantial increase in production costs (from $31,300 to $105,900) and average annual flood damages (from $11,600 to $29,900). In absolute terms, an increase in out-of-pocket expenditures (production costs) of $74,600 is required to increase net revenue $69,000. In other words, net revenue is increased approximately one dollar for each additional dollar of production costs resulting from the land use adjustment. The increase in capital requirements and risk (flood damages) are a consequence of adjusting from a low to a high value crop, i.e., intensification of flood plain use [8].

Table 2. Present and optimum flood plain land use patterns and associated dollar values without flood protection and with flood protection, Nuyaka Creek flood plain

Item	Unit	Present land use[a]		Optimum land use[b]	
		Without[c] protection	With[d] protection	Without[c] protection	With[d] protection
(1)	(2)	(3)	(4)	(5)	(6)
Crops					
Cotton	acre	10	10	—	—
Corn	acre	10	10	—	—
Soybeans	acre	35	35	1,435	2,370
Wheat	acre	55	55	—	—
Oats	acre	80	80	—	—
Barley	acre	35	35	—	—
Bermuda grass	acre	250	250	—	—
Alfalfa	acre	290	290	1,060	540
Native hay	acre	65	65	190	165
Woodland pasture	acre	1,745	1,745	630	450
Native pasture	acre	1,165	1,165	425	215
Flood plain values					
Gross revenue	$1,000	54.6	54.6	216.5	228.8
Production costs	$1,000	31.3	31.3	105.9	102.8
Average annual flood damages	$1,000	11.6	4.9	29.9	19.0
Net returns	$1,000	11.7	18.4	80.7	107.2
Net returns/acre	$	3.12	4.92	21.57	28.66

[a] Present land use refers to 1968 land use.
[b] Optimum land use is the profit-maximizing land use pattern for the flood plain.
[c] Without protection refers to present flood plain conditions or flood plain conditions before a flood protection project.
[d] With protection refers to flood plain conditions after a flood protection project is completed.

Flood protection benefits

Benefits of flood protection are usually measured by the reduction in average annual flood damages and include a value for land enhancement. The authors contend this is a major pitfall of project evaluation because it overstates benefits by crediting the project with returns resulting solely from land use changes. Studies of previously developed watersheds [2] indicate that a more intensive use of flood plain does not always result. An evaluation of a watershed in Texas [3] found that *less* rather than *more* intensive land use patterns had developed, the opposite of the change projected by project planners. It is not the intent here to outline the conditions under which increased returns resulting from land use adjustment should be included as benefits, but rather to indicate that the model being discussed provides a tool to separate the benefits of land use adjustment from those of flood protection.

One method of considering the effect of flood protection on an area is to assume that present land use does not change after the flood protection plan is put into effect. The effect of flood protection, assuming no change in land use, is shown for Nuyaka Creek by comparing average annual flood damages and expected net returns in columns 3 and 4 of Table 2. The flood protection plan reduces expected damages from $11,600 to $4,900 (or $6,700) and increases net returns from $11,700 to $18,400 (also $6,700). Thus, the benefits of flood protection, assuming no land use changes, are $6,700.

However, land use adjustments may occur as a result of construction of a flood protection plan. The land use pattern that maximizes re-

Table 3. Present land use, average annual flood damages assuming no flood protection and with flood protection, and the reduction in average annual flood damages attributable to flood protection for six selected sample points[a]

Sample[b] point	Present land use	Average annual flood damages: Without flood protection	Average annual flood damages: With flood protection	Benefits[c] of flood protection	Assessment[d] factor
(1)	(2)	(3)	(4)	(5)	(6)
		dollars	dollars	dollars	percent
1	W. pasture[e]	4.03	2.91	1.12	0.0166
2	Alfalfa	55.23	10.43	44.80	0.6657
3	W. pasture[e]	3.79	2.00	1.79	0.0266
4	W. pasture[e]	1.58	0.61	0.97	0.0144
5	Alfalfa	60.65	21.45	39.20	0.5825
6	Corn	225.75	185.28	40.47	0.6013
	Total	351.03	222.68	128.35	1.9071

[a] Present land use refers to 1968 land use.
[b] Each sample point represents five acres; hence, the values given in the table refer to five-acre units of flood plain.
[c] Benefits are measured by the reduction in average annual flood damages attributable to flood protection assuming present land use.
[d] Assessment factor refers to the percent of total flood plain flood protection benefits received by each sample point.
[e] Woodland pasture.

turns net of production costs and average annual flood damages for Nuyaka Creek is given in columns 5 and 6 of Table 2, without and with flood protection, respectively. The optimum land use with flood protection requires a cropping change on 1,405 acres. The changes indicated are primarily from alfalfa and pasture to soybeans. The flood protection and land use changes reduce expected flood damages $10,900 and increase net returns $26,500 (from $80,700 to $107,200). In this case, the benefits of flood protection are $26,500.

The extent to which land use adjustment benefits are considered in evaluating a watershed should probably be determined on a watershed-by-watershed basis. One interpretation of the above estimates of flood protection benefits is that the difference between net returns with and without flood protection for present land use ($6,700) is an estimate of the minimum benefits expected from flood protection, while the difference between net returns for the optimum land use with and without flood protection ($26,500) is an estimate of the maximum benefits expected from flood protection [8].

Assessing beneficiaries for flood protection

In addition to estimating the benefits of a flood protection project, it is necessary to assess the flood plain beneficiaries for specified project costs not included in legislative appropriations. The assessment criterion is each beneficiary shall be assessed in relation to the proportion of benefits received; that is, flood plain farmers are to pay specified flood protection costs in proportion to the total benefits received. The procedures reported in this article can be utilized to assess farmers based on either of two methods: (1) the reduction in damages incurred or (2) the increase in net returns for an optimum (profit-maximizing) flood plain land use pattern both with and without flood protection. These two methods have been compared in detail [6], but the issues can be illustrated by considering a few sample points.

Consider first assessments based on the reduction of flood damages. Table 3 lists present land use (1968 land use), average annual flood damages before and after flood protection, reduction in flood damages attributable to flood protection, and proportion of total Nuyaka Creek flood plain reduced damages (benefits) for each of 6 sample points. The final column of Table 3 gives the proportion of total Nuyaka Creek benefits by sample point. This proportion can be used to determine the percent of beneficiary project costs levied against each of the 6 sample points.

The assessment factor for a farmer is obtained by summing the assessment factors for the sample points that represent the farmer's land. The reduction in average annual flood damages over the aggregate Nuyaka Creek flood plain is $6,730, of which $128.35 is applicable to the 6 sample points of Table 3. In this case, 1.9071 percent of the total Nuyaka Creek assessment is allocated among the 6 sample points. Assuming the 6 sample points of Table 3 represent the flood plain of one farmer, the assessment levied against him for flood protection would be 1.9071 percent of the specified project costs.

A possible problem in basing assessments on the benefits for present land use can be noted. Sample points producing low-value crops (such as woodland pasture on sample point 1) tend to be characterized by smaller flood damage estimates than sample points producing higher value crops (such as alfalfa on sample point 2). Under the above procedure, two sample points with equal productivity, receiving the same reduction of flood frequency and inundation, might be assessed at quite different levels because their land use differs.

An alternative approach which avoids the above criticism bases assessments on the difference in net return for optimum land use before and after flood protection. Table 4 lists the information used to compute the assessments based on optimum land use. The increase in potential net returns attributable to flood protection is given in column 6 for each of the 6 sample points. The percentage of total Nuyaka Creek flood plain benefits by sample point, the assessment factor, is listed in column 7.

The increase in estimated net returns resulting from flood protection and appropriate land use changes is $26,516 for the total Nuyaka Creek flood plain and $202.03 for the six sample points (Table 4). Benefits of flood protection are the same in Tables 3 and 4 for sample point 1 ($1.12). However, the assessment factor based on optimum land use is only one-fourth the assessment based on present land use (0.004 percent in Table 4 compared to 0.0166 percent in Table 3). The present land use, as well as the optimum land use on sample point 2, is a high value crop resulting in similar benefits of flood protection for sample point 2 in Tables 3 and 4. However, the assessment factor in Table 4 is only 0.180 compared with 0.6657 in Table 3. Sample points 1 and 2 indicate that locations characterized by approximately the same present and optimum land use tend to have a smaller assessment under the optimum land use procedure than under the reduced damages procedure.

Data of Tables 3 and 4 indicate the optimum land use procedure tends to assign larger assessments to sample points where it is profitable to shift from a low to a high value crop. For example, the benefits of flood protection for sample point 4 are much larger in Table 4 ($88.30) than in Table 3 ($0.97). Consequently, the assessment factor based on optimum land use is much larger than one based on reduced damages (0.33 percent compared with 0.0144 percent).

The assessment factor for the 6 sample points is 0.762 percent based on optimum land use, compared with 1.9071 percent based on reduced damages. This comparison indicates significant differences may result depending on the method selected. The model discussed can be applied with either.[12]

Table 4. Optimum land use and expected net returns without flood protection and with flood protection and the potential increase in net returns attributable to flood protection for six selected sample points

Sample[a] point	Without flood protection: Optimum[b] land use	Without flood protection: Net returns	With flood protection: Optimum[b] land use	With flood protection: Net returns	Benefits[c] of flood protection	Assessment[d] factor
(1)	(2)	(3)	(4)	(5)	(6)	(7)
		dollars		dollars	dollars	percent
1	W. pasture[e]	4.72	W. pasture	5.84	1.12	0.004
2	Alfalfa	166.37	Soybeans	214.09	47.72	0.180
3	W. pasture[e]	4.96	Native hay	11.74	6.78	0.026
4	Alfalfa	33.84	Alfalfa	122.14	88.30	0.333
5	Soybeans	160.95	Soybeans	205.35	44.40	0.167
6	N. pasture[f]	18.42	Native hay	32.13	13.71	0.052
	Total	389.26		591.29	202.03	0.762

[a] Each sample point represents five acres.
[b] Land use that maximizes returns net of production costs and average annual flood damages.
[c] Benefits of flood protection are measured by the increase in estimated net returns assuming an optimum sample point land use before and after flood protection.
[d] The assessment factor is the percent of total flood plain protection benefits (the potential increase in net returns) each sample point receives.
[e] Woodland pasture.
[f] Native pasture.

Agricultural flood insurance

The final application of the model considered in this paper is in establishing annual flood insurance premiums. Insurance involves substituting a smaller but sure annual cost for a small probability of a larger loss. Considering flood damages over the very long run for a particular flood plain field, average annual flood damages are analogous to the smaller but sure annual cost. Therefore, the annual premium, not including administrative costs, is derived by computing average annual flood damages in a given field for a specific land use assuming the farmer insures at a level equal to the expected gross value of the crop in the absence of flooding.

Average annual flood damages for present land use without flood protection and with flood protection are given in Table 3 for the area represented by 6 sample points. The annual flood insurance premium for the five acres represented by each sample point without flood protection is presented in column 3 of Table 3. The range of annual premiums over the 6 sample points is from $1.58 to $225.75.

Assuming the 6 sample points represent the

[12] The authors recognize that basing assessments on optimum land use as well as on a preproject land use is subject to criticism. A third alternative is to base the annual assessment on the reduction in flood damages provided by the watershed project for the crops actually produced. Total assessments for the watershed would be constant from one year to the next, but the distribution among beneficiaries would change as land use changed. This approach can also be implemented with the model.

flood plain acreage one farmer is going to insure, the annual premium with no flood protection is $351.03. With flood protection and the same land use, the farmer's premium would total $222.68 (column 4, Table 3) for the 6 sample points. If the farmer operates the 6 sample points as one 30-acre field, the model also can be used to estimate the premium (average annual flood damages) when the 6 sample points are planted to the same crop.

Compulsory flood insurance or flood plain occupancy charges with indemnification for losses incurred are advocated by some to bring about desirable land use adjustments [5, pp. 166–169; 11, p. 38]. The procedure involves collecting an annual levy from each flood plain farmer based on the average annual damages of the crops produced in the bottomland. The optimizing routine described may be used to compute average damages, the levy rates, for as many as 15 crops on each sample point.

Conclusions

Two criticisms of the procedure discussed as a general model for evaluating agricultural flood plains are evident. The first is that it considers only agricultural production. Flood damages to buildings, fences, roads, and other improvements are not included. Reduction in these losses as well as other benefits such as recreation must be considered outside of the model.

A second criticism arises because land is the only resource constraint considered by the model in selecting optimum land use. The profit-maximizing use of flood plain land on farms may differ somewhat from the model optimum because the amounts of upland, labor, capital, and allotments available may influence the intensity of flood plain use. However, the model can be used to estimate the repercussions of alternative land uses at each flood plain location. In this way the farm operator can make a better selection of the combination of risk and expected returns he desires. Those watersheds justifying a more complete specification of the farm organization framework can combine linear programming procedures with the model described to select optimum land use. Expected returns net of production costs and average annual flood damages can be estimated for alternative crops on each sample point (or field) in the flood plain with the model discussed in this article. These net return estimates can be used in developing a linear programming model for each farm having land in the flood plain. The land use specified by the linear programming solutions can be used by the model as the basis for educational programs, computing assessment rates, and other analyses

Although the above problems are important, applying the model to the Nuyaka Creek flood plain indicates that the increase in expected net returns for appropriate land use changes exceeds the benefits of flood protection. This suggests that government agencies involved in watershed planning may want to apply the model discussed in this article as the basis for a flood plain development strategy. The strategy would require an initial effort to inform farmers of the profit-maximizing land use, perhaps through cooperation of the planning agencies and the state extension service. This work should be conducted before approval or construction of a flood protection plan. After farmers have indicated the extent to which they are willing to make adjustments in their farming operation, flood protection alternatives could be evaluated. Then farmers could be informed again of the profit-maximizing land use in conjunction with installation of flood protection.

References

[1] BERRY, BRIAN J. L., *Sampling, Coding, and Storing Flood Plain Data*, USDA, ERS, Agr. Handbook 237, Aug. 1962.

[2] COOK, NEIL R., *Effects of Upstream Flood Protection on Land Use*, Okla. Agr. Exp. Sta. Processed Series P-501, April 1965.

[3] GRAY, ROY MACK, AND WARREN L. TROCK, *An Economic Evaluation of the Green Creek Watershed Project*, Texas Agr. Exp. Sta. Tech. Rep. 2, Dec. 1968.

[4] KNETSCH, JACK L., ROBERT H. HAVEMAN, CHARLES W. HOWE, *et al.*, *Federal Natural Resource Development: Basic Issues in Benefit and Cost Measurement*, Washington, D.C., Natural Resources Policy Center, George Washington University, May 1969.

[5] LACEWELL, RONALD D., "An Economic Evaluation of the Nuyaka Creek Flood Plain Utilizing a General Model to Estimate the Incidence of Agricultural Flood Damages," unpublished Ph.D. thesis, Oklahoma State University, Jan. 1970.

[6] ———, AND VERNON R. EIDMAN, "A Proposed Procedure for Distributing Assessments Among Beneficiaries of Small Watershed Projects," *Southern J. Agr. Econ.* 2:139–145, Feb. 1970.

[7] ———, AND ———, *Expected Production Requirements, Costs and Returns for Alternative Crop Enterprises; Bottomland Soils of East Central and South Central Oklahoma*, Okla. Agr. Exp. Sta. Processed Series P-606, April 1969.

[8] ———, AND ——— *Using Computers to Help Evaluate Flood Protection Measures*, Okla. Agr. Exp. Sta., *Okla. Current Farm Econ.* 42:5–11, Dec. 1969.

[9] SLOGGETT, GORDON, AND NEIL COOK, *Evaluating Flood Prevention in Upstream Watersheds with an Areal Point Sample—Interim Report, Washita River Basin, Oklahoma*, USDA, ERS, NRED, July 1967.

[10] TOMLINSON, JIM, AND CECIL D. MAYNARD, *Native Pecan Production Costs and Returns*, Okla. Agr. Ext. Serv. Leaflet L-109, July 1967.

[11] U. S. Congress, House of Representatives, Task Force on Federal Flood Control Policy, *A Unified National Program for Managing Flood Losses*, House Document 465, 89th Cong., 2nd Sess., Aug. 10, 1966.

[12] U. S. Department of Agriculture, Soil Conservation Service, *Work Plan for Watershed Protection, Flood Prevention, Agricultural Water Management and Non-Agricultural Water Management; Okfuskee Tribidaries Watershed*, tentative draft, Nov. 1966.

[13] U. S. Government, Interdepartmental Staff Committee of the Water Resources Council, *Interim Price Standards for Planning and Evaluating Water and Land Resources*, April 1966.

Short Articles and Notes

Present Status of Quantitative Techniques in Undergraduate Agricultural Economics Programs*

LONNIE L. JONES, CURTIS F. LARD, AND LESTER V. MANDERSCHEID

Undergraduate training in quantitative analysis has undergone considerable change in recent years. Attempts have been made to raise the level of mathematical and statistical sophistication of agricultural economics undergraduate majors. However, in most undergraduate programs computer technology and econometric modeling are still relatively underutilized teaching and learning devices.

NEED FOR ENHANCING agricultural economics undergraduates' expertise with quantitative techniques has been expressed on previous occasions in this *Journal* [1, p. 285; 6]. While much of this attention has been directed toward broadening educational goals or improving teachers, some have addressed themselves to the question of appropriate requirements of specific subject matter areas in an agricultural economics curriculum, both graduate and undergraduate [2, 3, 4]. In 1965, Tolley and Grubb [5, pp. 189–206] reported the results of a survey of graduate training in mathematics and statistics in agricultural economics departments in the U.S. A wide disparity was found to exist among departments in requirements of mathematics and statistics training.

A report of the Commission of Education in Agriculture and Natural Resources (CEANAR) dealt with courses, credit hours, and level of difficulty of quantitative techniques subjects for undergraduate students in the fields of agriculture and natural resources [2, p. 19]. For terminal B.S. degree students (technology), a total of 15–18 hours of mathematics, statistics, and computer science was recommended by CEANAR. For those planning to enter graduate school (science), 19–22 hours were recommended with greater emphasis being placed on theory and principles [2, p. 33].

The purpose of the present article is to examine undergraduate curricula in agricultural economics in the U.S. and Canada with respect to quantitative techniques. In particular, current content and proposed directions for change were examined to draw some conclusions concerning the adequacy of current and proposed undergraduate quantitative curricula in meeting the needs of agricultural economics majors.

The Survey

Information on quantitative methods courses was based on responses from a national mail survey of agricultural economics departments conducted in the spring of 1970. Questionnaires requesting data on size of department, degrees offered, methods of training students in quantitative techniques, credit hours of specified quantitative subjects taken by "typical" undergraduate majors,[1] and recent changes in requirements were mailed to 78 departments offering an agricultural economics curriculum at the bachelor level.

Fifty-five departments completed the questionnaire sufficiently for use in this analysis. Thirty-four of the responding departments offered B.S., M.S., and Ph.D. degrees in agri-

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LONNIE L. JONES is assistant professor and CURTIS F. LARD is associate professor of agricultural economics at Texas A&M University. LESTER V. MANDERSCHEID is professor of agricultural economics at Michigan State University.

[1] Respondents were asked to indicate subjects and course hours taken by typical students since these may exceed basic requirements. However, in later discussion concerning curricular changes and plans for change, respondents were asked to refer specifically to requirements since this provided a more meaningful base for comparing changes over time.

cultural economics. Fifteen offered B.S. and M.S. degrees and six offered only the B.S. degree. Respondents were chiefly from land grant universities with a reported total undergraduate and graduate enrollment in agricultural economics of 5350 students in 1969–70. Responses were received from two departments in Canada and all but three states in the United States.

Current Quantitative Techniques Curricula

Responding departments were grouped into two categories for purposes of analyzing current quantitative techniques curricula in agricultural economics. The first category included 24 departments that reported a distinction between majors planning to attend graduate school (science majors) and those planning to terminate their formal education at the bachelor level (non-science majors). The second category of 31 departments made no distinction for the two types of students. However, eight departments in this second category indicated that informal, personal counseling was used to influence students to take more or fewer quantitative courses depending upon the individual's plans and aptitude for graduate study.[2]

Quantitative courses

Quantitative courses taken by typical science and non-science undergraduates in departments making a formal distinction in requirements are presented in Table 1. Courses taken by typical students in departments with no formal distinction in requirements are shown in Table 2. In nearly all departments, students typically study algebra and introductory statistics, although "probability" is taken by non-science students in only about two-thirds of the departments that classified their students into the two categories. For other quantitative subjects listed in Table 1, science majors typically take more quantitative subjects than non-science majors in nearly all departments. As expected, majors in departments that make no distinction typically take more quantitative subjects than do non-science majors in departments that did make the distinction. A most striking difference exists among the three groups of students in mathematics courses above the introductory (algebra) level. Typical science majors in 92 percent of departments take differential calculus and 62 percent take integral calculus. Typical non-science majors in 42 percent of departments take differential calculus and integral calculus in only 12 percent (Table 1). In departments that make no distinction, these percentages are 55 and 23 percent for differential and integral calculus, respectively (Table 2). Few uniformities exist among departments beyond the basic introductory courses in mathematics and statistics.

Although no consistent relationship between size of department and extent of quantitative studies is discernable, students in departments offering graduate degrees typically study more quantitative subjects beyond the introductory level than students in departments offering only a B.S. degree (Tables 1 and 2).

Semester hours

Modal and mean semester hours of quantitative techniques taken by typical undergraduate majors in agricultural economics are shown in Table 3.[3] For departments that distinguish between science and non-science majors, approximately 27 semester hours of quantitative course work are taken by typical science students. Non-science majors average about one-half this many hours. In departments that make no distinction between types of students, about 19 semester hours are taken by typical students (Table 3).

Courses in the "other math" category most commonly included finite mathematics, mathematics of finance of business, mathematics for social sciences, and modern mathematics. For "other statistics" these were general and business statistics and sampling.

Curricular Characteristics and Plans for Change

In addition to specifying current quantitative techniques curricula, respondents were asked to provide information on characteristics of their programs and recent and anticipated changes in requirements. These responses provided some insight into the way quantitative

[2] The authors realize that undergraduate students do not fall neatly into the two categories used. Plans of individual students change continuously throughout their undergraduate program. Nevertheless, 24 of the 55 responding departments categorized students as either terminal at the B.S. level or preparing for graduate school and made a formal distinction in quantitative requirements on this basis. Hence, the dichotomy provides a framework for analyzing undergraduate quantitative programs.

[3] All course hours are reported on a semester basis. Course hours reported by respondents on the quarter system were converted to semester hours using the ratio of 1.0 semester hour = 1.5 quarter hours.

Table 1. Quantitative subjects taken by typical science and non-science undergraduate majors by department, 1969–70 school year

Department at:	Number of students		Highest degree offered	Mathematics						Statistics					Linear programming and other operations research[1]	Computer science	Math Economics and/or etrc.†
	Science	Non-science		Algebra	Trig.	Matrix algebra	Differential calculus	Integral calculus	Other math	Probability	Regression	Analysis of variance	Math statistics	Other statistics			
Clemson Univ.	5	83	PhD	S, N[3]	S, N	—	S, N	S, N	—	S, N	S, N	S, N	—	—	S, N	—	—
Univ. Connecticut	1	4	PhD	S, N	—	S	S, N	S	—	S, N	S	S	—	—	S	—	—
Cornell	100	300	PhD	S, N	S	S	S, N	S	—	S	S, N	—	—	—	—	S	S
Univ. Florida[2]	7	43	PhD	S, N	S, N	—	S, N	S	—	S, N	S, N	S, N	—	S	N	S, N	S, N
Univ. Illinois	52	134	PhD	S, N	—	—	S, N	S, N	S, N	S, N	S, N	S, N	—	—	—	—	—
Iowa State[2]	*	*	PhD	S, N	S	S, N	S	—	—	S, N	S, N	S, N	—	—	S	S, N	—
Kansas State	38	150	PhD	S, N	S	—	S	S	—	S	N	S	—	—	—	S, N	—
Univ. Kentucky	4	35	PhD	—	—	—	S	—	—	S, N	—	—	—	—	—	—	—
Univ. Manitoba	7	14	PhD	—	—	S, N	S, N	—	—	S, N	S, N	S	S	N	S	S, N	S, N
Mississippi State	0	83	PhD	S, N	S, N	—	—	—	—	S, N	S	—	—	—	—	—	S, N
Univ. Missouri	15	265	PhD	S, N	S, N	S	S	S	S, N	S	S	S	S	S, N	S	S, N	S
Montana State	12	173	PhD	S, N	S, N	—	S	S	—	S, N	S	S, N	—	—	—	—	—
Morehead State	2	35	BS	S, N	S, N	—	S	—	—	S	S	S	—	—	—	N	—
Univ. Nebraska[2]	35	165	PhD	S, N	S	S	S	S	—	—	—	—	—	S, N	S	—	—
New Mexico State	15	135	MS	S, N	S, N	S	S	S	—	S, N	S	S	—	—	—	S, N	S
North Carolina State[2]	5	70	PhD	S, N	S, N	—	S, N	S, N	—	S, N	—	—	—	—	—	—	—
North Dakota State	50	200	MS	S, N	S, N	S	S, N	S	—	S, N	S	—	—	—	—	S	—
Oklahoma State	70	280	PhD	S, N	S	S	S, N	S	—	—	—	—	S	S, N	S	S	—
South Dakota State	40	210	PhD	S, N	S, N	—	—	—	S, N	S	S, N	S	—	—	—	—	S
Tennessee Tech	1	8	BS	S, N	S	—	S	—	—	S, N	—	—	—	—	—	S, N	—
Texas Tech	8	190	MS	S, N	S	—	S	—	—	—	S, N	S, N	S	—	—	S	S
Virginia Tech[2]	5	42	PhD	S, N	S, N	S	S, N	S	N	S, N	S, N	S, N	—	—	—	S, N	—
Washington State	15	70	PhD	S, N	S	S	S	S	—	S, N	S, N	S	—	—	S	S	—
Univ. Wyoming	3	73	MS	S, N	S, N	—	S	—	—	S, N	S	—	—	N	—	—	—

[1] Other operations research includes decision theory and mathematics programming.
[2] Respondents gave incomplete breakdown of subjects. Allocations made by authors' judgment, department bulletin and/or other information.
[3] S = science student, N = non-science student.
* Information not provided.
† Etrc. = Econometrics.

Table 2. Quantitative subjects taken by typical undergraduate agricultural economics majors at departments that make no distinction in requirements, 1969–70 school year[1]

Department at:	Number of students	Highest degree offered	Mathematics: Algebra	Trig.	Matrix algebra	Differential calculus	Integral calculus	Other math	Statistics: Probability	Regression	Analysis of variance	Other statistics	Linear programming and other operations research[5]	Computer science	Math Economics and/or etrc.†
Univ. Alberta	60	PhD	—	—	x[4]	x	x	—	x	x	x	—	x	x	x
Univ. Arizona[2]	68	PhD	x	x	—	—	—	x	x	—	—	—	—	—	—
Univ. Arkansas	84	MS	x	—	—	—	—	—	x	x	—	—	—	x	—
Auburn Univ.[3]	70	MS	x	x	x	x	x	—	x	x	x	—	x	—	x
Univ. California at Davis	115	PhD	—	—	x	x	x	—	x	x	—	x	x	—	x
Colorado State	*	PhD	x	—	—	x	x	—	x	x	x	—	—	—	—
Univ. Delaware	45	MS	x	—	—	x	—	—	x	x	x	—	—	—	—
Univ. Georgia	86	MS	x	x	—	—	—	—	x	—	—	—	—	—	—
Univ. Idaho	84	MS	x	x	—	x	—	—	x	—	—	—	—	—	—
Illinois State	450[3]	BS	x	—	—	—	—	—	—	—	—	—	—	x	—
Louisiana State	64	PhD	x	x	—	—	—	—	—	x	—	x	x	x	—
Univ. Maine	120	MS	x	x	—	x	—	—	x	x	—	—	—	x	—
Univ. Maryland	24	PhD	x	—	x	—	—	—	x	x	x	—	—	—	—
Univ. Massachusetts	50	PhD	x	—	—	x	—	—	x	x	—	—	x	x	—
Middle Tennessee	238[3]	BS	x	x	—	—	—	—	x	—	—	—	—	—	—
Michigan State	30	PhD	x	x	—	—	—	—	x	x	x	x	x	x	—
Univ. Minnesota	150	PhD	x	—	—	x	—	—	x	—	—	—	x	—	—
Univ. Nevada at Reno	33	MS	x	x	—	—	—	x	x	x	x	—	—	—	—
Ohio State	200	PhD	x	x	x	x	—	—	x	—	—	—	—	x	x
Oregon State	75	PhD	—	—	—	x	x	—	x	x	x	—	x	x	x
Penn State[3]	60	PhD	x	x	—	x	—	—	x	—	x	—	x	x	—
Purdue Univ.	250	PhD	x	x	—	x	—	—	x	x	x	—	x	x	—
Rutgers	150	MS	—	—	—	x	x	—	x	x	x	—	x	x	—
Southern Illinois	100	MS	x	—	—	x	—	—	x	x	x	—	—	—	—
Texas A&I	45	MS	x	—	—	—	—	—	—	—	—	x	—	—	—
Texas A&M	240	PhD	x	x	—	—	—	x	x	x	—	—	—	—	x
Univ. Tennessee	56	PhD	x	—	—	x	x	—	x	x	x	—	x	—	—
West Virginia	22	MS	x	—	—	—	—	—	x	x	—	—	x	—	—
Western Illinois	85	BS	x	x	—	—	—	—	—	—	—	x	x	x	—
Univ. of Wisconsin	80	PhD	x	x	—	x	—	—	x	x	—	—	x	x	—

[1] One respondent in this category could not be identified by name although the questionnaire was used in other analyses.
[2] Respondents gave incomplete breakdown of subjects. Allocations made by authors' judgment, department bulletin and/or other information.
[3] College or department of agriculture.
[4] x = course taken by typical students.
[5] Other operations research includes decision theory and mathematics programming.
* No information provided.
† Etrc. = Econometrics.

Table 3. Modal and mean quantitative semester hours taken by typical undergraduate majors in agricultural economics, 1969–1970 (55 colleges and universities)

Subject classification	Science		Non-science		No distinction	
	Mode	Mean	Mode	Mean	Mode	Mean
			(Semester hours)			
Mathematics:						
Algebra	3	2.76	3	2.88	3	3.19
Trigonometry	3	2.52	3	1.56	0	1.45
Matrix Algebra	3	1.44	0	0.24	0	0.48
Differential Calculus	3	3.84	0	1.32	3	1.55
Integral Calculus	3	2.64	0	0.36	0	0.58
Other	0	0.60	0	0.60	0	0.29
Total hours		13.80		6.96		7.54
Statistics:						
Probability	3	2.88	3	2.41	3	2.52
Regression	3	2.28	0	1.08	3	2.03
Analysis of Variance	3	1.92	0	0.72	0	1.26
Mathematical Statistics	0	0.72	0	0.00	0	0.19
Other	0	0.60	0	0.84	0	0.58
Total hours		8.40		5.05		6.58
Operations Research:						
Linear Programming	0	0.72	0	0.24	0	1.26
Decision Theory	0	0.12	0	0.12	0	0.68
Mathematical Programming	0	0.00	0	0.00	0	0.29
Other	0	0.00	0	0.00	0	0.19
Total hours		0.84		0.36		2.42
Computer Science	3	2.04	0	1.20	3	1.64
Mathematical Economics	0	0.96	0	0.12	0	0.29
Econometrics	0	0.60	0	0.24	0	0.29
Grand total of hours required		26.64		13.93		18.76

techniques subject matter is taught in agricultural economics departments and changes that may be expected in the near future.

The significant upward trend in the use of quantitative techniques in the profession has permeated the undergraduate instruction programs in most departments. More than 60 percent of the departments indicated they had increased quantitative requirements for all undergraduates during the five years preceding the 1969–70 school year. Only 6 percent decreased requirements for science majors and 2 percent for non-science majors.

More than one-half of all respondents anticipated no further changes in quantitative curricula for either science or non-science majors. Some respondents indicated plans for increasing requirements, and none indicated plans to decrease requirements below their current level.

As quantitative requirements increased in the past five years, primary emphasis was placed on mathematics and statistics. Mathematics courses were mentioned 18 times as courses added to curricula and statistics courses were mentioned 12 times. Seven departments added computer science courses required for both science and non-science majors. Six departments added courses in operations research, including linear programming.

Departments responded most frequently that past requirements in technical agriculture and the physical sciences were reduced as quantitative requirements were increased. Seventeen departments stated they had dropped courses in the physical or biological sciences such as physics, chemistry, and biology. Ten indicated technical agriculture courses were eliminated and three discontinued other agricultural economics courses as requirements. Nine departments reduced the number of electives previously available to students without reducing other specific course requirements.

Summary and Conclusions

Data from the survey indicate a wide disparity among departments in courses taken by typical students beyond introductory mathematics and statistics. An examination of individual responses indicates that beyond these basic levels, training in quantitative techniques for all groups of students ranges from practically non-existent to quite elaborate.

Quantitative requirements for undergraduate majors increased sharply in recent years with primary emphasis in mathematics and statistics. Computer science and linear programming also have been added to requirements in some departments. These changes

were accomplished in most departments by reducing requirements in physical and biological sciences.

Quantitative studies by typical non-science majors are composed almost entirely of basic mathematics and statistics with virtually no exposure to more "interpretative" subjects such as econometrics and mathematical economics (see Table 1). This implies that non-science majors in most departments have little opportunity prior to graduation to apply their quantitative training in conjunction with economic theory in solving problems. For the science major, such opportunity is usually afforded in graduate studies. But the non-science major may end his formal training with little if any insight into how economic theory, mathematics, and statistics may be integrated and applied in a meaningful problem-solving context.

Identifying science and non-science majors early in their programs and committing limited departmental resources to separate programs of study are recognized as difficult administrative and counseling problems. Nevertheless, it is suggested that for non-science students more emphasis should be placed on the application of quantitative techniques to problems in agriculture and agribusiness. This might be accomplished in one senior level 3-hour course in introductory econometrics. An alternative is to insure that junior and senior level courses in agricultural economics use the prior quantitative training in a problem-solving context. An understanding of these methods will be essential for future agricultural managers if they are to use research from public institutions effectively and deal with increasingly technical problems in their own occupations.

A second curricular suggestion is that student exposure to the use of computer technology should be increased for all agricultural economics majors. Students need an appreciation of the merits and limitations of applying computer technology to agricultural problems. This has been a primary recommendation by industrial economists and others in the past [1, p. 1601; 6]. Yet, students take computer science courses in fewer than one-half of all departments (Tables 1 and 2). These departments cannot and should not graduate computer experts. But a working knowledge of how computers may be used (and misused) can contribute significantly to decision making and problem solving in agricultural economics.

A number of respondents expressed a need for improved communications concerning undergraduate quantitative training and other curricular questions that are well beyond the scope of this paper. To partially fulfill this need, the authors suggest that the editors of this *Journal* encourage such communication by providing a continuous, systematic means through which teachers, both graduate and undergraduate, might exchange ideas on current developments and needed changes in curricula and new teaching methods.

Further, it is recommended that the recently appointed American Association of Agricultural Economics Committee on Education direct its attention to consideration of curricular needs, including quantitative techniques, of *both* science and non-science majors in agricultural economics. The CEANAR report has been useful in establishing long-run curricular guidelines for students in agriculture and natural resources. Although agricultural economics is included in this broad field, the CEANAR report did not make recommendations specifically for agricultural economics undergraduate majors. Curricular recommendations by the Committee on Education developed from an in-depth study of agricultural economics undergraduate curricular needs would be a significant contribution to guidelines currently available for use by individual departments and academic advisors.

References

[1] COATS, NORMAN M., "Appraisal of the Current Training of Economists for Positions in Industries Serving Agriculture," *J. Farm Econ.* 48:1600–1603, Dec. 1966.

[2] Commission on Education in Agriculture and Natural Resources, "Undergraduate Education in the Physical Sciences and Mathematics for Students in Agriculture and Natural Resources," National Academy of Sciences-National Research Council, Washington, D.C., 1970.

[3] JAMES, H. BROOKS, "Objectives of Undergraduate Education and the Role of Agricultural Economics for Agricultural Economics Majors," *J. Farm Econ.* 49: 281–285, Feb. 1967.

[4] KELLOGG, LESTER S., "Training of Economists for Positions in Industries Serving Agriculture," *J. Farm Econ.* 48:1595–1599, Dec. 1966.

[5] TOLLEY, G. S., AND H. W. GRUBB, "Mathematics and Statistics in Graduate Agricultural Economics Training," *J. Farm Econ.* 47:189–206, May 1965.

[6] WALKER, F. E., AND D. I. PADBERG, "The Impact of Computers on the Teaching of Quantitative Methods," *J. Farm Econ.* 46:1029–1031, Dec. 1964.

Distributed Lag Models of Cotton Acreage Response: A Further Result

WILLIAM G. TOMEK

The sensitivity of empirical results to changes in model specification is illustrated for a geometric-form distributed lag model of cotton acreage response. One plausible specification gives a distributed lag response of acreage to price. Another logical, and perhaps more reasonable, specification indicates no distributed lag response.

SIXTEEN YEARS AGO Nerlove [5] presented an important paper which described a geometric-form distributed lag model, including applications to supply functions for corn, cotton, and wheat.[1] A measure of the importance of this paper is its reproduction in *Readings in the Economics of Agriculture* [3]. The author here returns to Nerlove's work with the intent of fitting alternative distributed lag models to similar data.

In estimating acreage response functions for cotton, it became clear that changing the nature of the "supply shift" variables in the equation fundamentally changed the conclusion about the existence of a lag.[2] The purpose of this note is to illustrate the sensitivity of empirical results to changing model specifications; the intent is *not* to criticize Nerlove's basic contribution. It is difficult to test for the correctness of a total model specification, and therefore it is useful to have examples of alternate results, particularly when they are quite different. A constant reminder that "statistical inference . . . is conditional upon the validity of the model" [4, p. 44f] is necessary.

The now well-known equation estimated by Nerlove is of the form

$$A_t = \pi_0 + \pi_1 P_{t-1} + \pi_2 A_{t-1} + \pi_3 t + u_t,$$

where

A_t = cotton acreage planted (in cultivation July 1), million acres,
A_{t-1} = A_t lagged one year,
P_{t-1} = season average farm price of cotton, deflated (deflators to be discussed), cents per pound,
t = linear trend or time,
π'_s = the parameters to be estimated, and
u_t = the unknown disturbances.

Nerlove estimated this equation for the time period 1909–1932, and the cotton price was deflated "by a Fisher ideal index of the prices received for twelve important crops" [6, p. 198]. This index apparently is one computed by Strauss and Bean [7, Table 80], and the price of cotton is a component of the index. The resulting regression is reported as equation (1) in Table 1. Another approach is to consider cotton prices relative to input prices and deflate by the Index of Prices Paid by Farmers (1910–14 = 100).[3] The dependent variable includes observations for 1910–33, the lagged variables 1909–32.[4] The result is presented as equation (2) in Table 1. The change in deflator makes a difference in the price and trend coefficients, but the lagged dependent variable coefficients in equations (1) and (2) are very similar. Both regressions do lead to the same conclusion: a significant distributed lag effect exists.

Inspection of scatter diagrams such as Figures 1 and 2 (always a good preliminary step) suggests that a linear trend may be a poor method of allowing for changes in supply. The principal shift in supply occurred abruptly between 1924 and 1925. This shift does not seem explainable in terms of changes in relative prices (i.e., changes in cotton prices relative to input prices or relative to other product prices). According to Walsh [8, p. 364], the change

[1] A more detailed account of the supply estimates is given in [6], and this note relies heavily on that reference.

[2] Brandow [1] has stressed the possible consequences of omitting a relevant explanatory variable.

[3] Equations (2) through (5) are based on data in [8, p. 368, Table 3]. The price deflator is the index of prices paid by farmers (all items). Walsh [8, p. 361] argues that the all items index is relevant because family living expenses are a cost in plantation-type argiculture. However, the use of the index for production items only would make little difference.

[4] The 1933 observation on planted acres may be used because cotton was planted prior to the adoption of new farm legislation. Cotton was "plowed up" in 1933, and harvested acres were 11 million smaller than planted [8, p. 360].

WILLIAM G. TOMEK *is professor of agricultural economics at Cornell University.*

Table 1. Cotton acreage response relationships

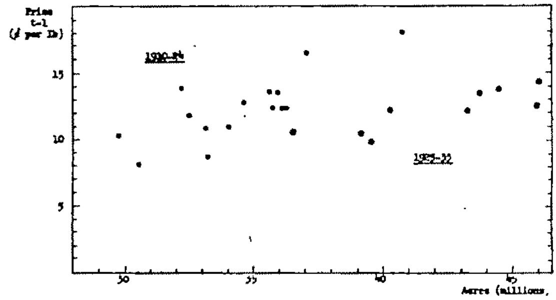
Equation	Independent variables[a]						
	P_{t-1}	A_{t-1}	t	D	intercept	R^2	d
(1)[b]	.655 (.196)	.592 (.169)	.177 (.123)[c]	—	4.994	.74	2.34
(2)[d]	.566 (.154)	.565 (.150)	.271 (.104)	—	6.319 (5.396)	.75	1.60
(3)	.758 (.097)	—	—	9.939 (.719)	24.601 (1.329)	.90	1.14[e]
(4)	.749 (.100)	.068 (.127)	—	9.352 (1.321)	22.417 (4.312)	.90	1.19
(5)	.754 (.102)	.058 (.130)	−.058 (.087)	10.142 (1.794)	23.126 (4.502)	.91	1.25

[a] Variables are defined in text.
[b] Equation (1) is Nerlove's result as reported in [6, p. 201, Table XXXII].
[c] Numbers in parentheses are estimated standard errors.
[d] Equations (2) through (5) are author's results based on data in [8, p. 368, Table 3]. Thus, the definition of P_{t-1} differs from the one used in equation (1).
[e] The Durbin-Watson test for first-order autocorrelation in equations (3) through (5) are inconclusive, but the fairly small values of d are suggestive of autocorrelation. (The Durbin-Watson test is not applicable to models containing a lagged dependent variable, but the statistic is presented for purposes of comparison of results.)

apparently resulted from "(1) control of the boll weevil, and (2) expansion of cotton into . . . the Southwest." On the other hand, Nerlove writes [6, p. 80], "These factors, however, hardly seem the kind to have produced an abrupt shift." While the merits of Walsh's arguments may be questionable, a shift in supply appears to be an empirical reality.

The nature of the shift does differ with the deflator used. Logically, the relevant input and competing product prices should be included in the equation, but from a practical viewpoint, neither index is a particularly close proxy for these concepts. Both indices are, to some extent, simply reflecting changes in a "general" price level. The product (12 crop) index also has the disadvantage of including the price of cotton as a component; deflating a price series by an index which contains that series as a component biases the regression coefficients [e.g., 2, p. 28]. This may explain, at least in part, the "flatness" of the scatter in Figure 1 relative to Figure 2.

When the 12 crop price index is used as the deflator (Fig. 1), the hypothesis of equal parameters in the two periods is rejected.[5]



[a] Deflator includes price of cotton—see text.

Figure 1. Cotton acreage in cultivation July 1 related to lagged price of cotton deflated by index of 12 crop prices,[a] 1910–33

However, when the Prices Paid Index is used as the deflator, the hypothesis of equal slope coefficients is accepted. Thus, a model which permits only a shift in the intercept is used. The variable D (Table 1) takes the value zero for 1910–24 and the value one for 1925–33. This dummy variable provides a measure of the shift in supply whatever its reason.[6]

Equation (3) contains only the dummy variable and lagged price, and the residuals appear autocorrelated. Such autocorrelation could arise from a distributed lag effect, hence from the omission of the lagged dependent variable. But the hypothesis of a zero parameter for the lagged acreage variable is accepted (equation (4)).[7] A few other model specifications contain-

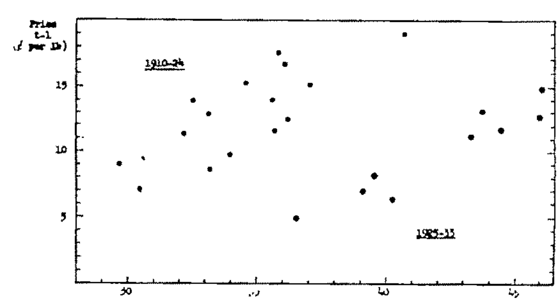


Figure 2. Cotton acreage in cultivation July 1 related to lagged price of cotton deflated by index of prices paid, 1910–33

[5] The results of this pooled regression are *not* the same as those reported by Nerlove (and as repeated in Table 1 of this note). Hence, the data used in this note (as depicted in Figure 1) may differ from those used by Nerlove. Nonetheless, the coefficient of lagged acreage is "highly significant" in the pooled-data regression based on the Strauss and Bean deflator. Therefore, all of the regressions based on the total time period using trend as a shift variable and using different deflators lead to the conclusion of a significant lagged effect.

[6] Walsh [8, p. 365] estimates separate equations for the two periods.

[7] The coefficient of lagged acreage also is not significantly different from zero when separate equations are estimated for the two time periods.

ing a geometric distributed lag were considered (e.g., equation (5)), but the coefficient of lagged acreage is not significantly different from zero in any of these equations. In addition, a few equations were reestimated by a method taking account of first-order autocorrelation, but the results were similar to those obtained using ordinary least squares.

The following model was estimated for the cases of $n=2$ to $n=4$ in a further attempt to measure potential lags.

$$A_t = \alpha_0 + \alpha_1 D + \sum_{i=1}^{n} \beta_i P_{t-i} + e_t,$$

where the variables are as defined above (with the Prices Paid deflator). The intercorrelations among the various lagged prices are surprisingly small, but the hypotheses that the parameters of P_{t-2}, P_{t-3}, and P_{t-4} are zero are accepted in all cases. No measurable lag—beyond one year—exists for those specifications which use a zero-one variable to account for the abrupt supply shift.

The residuals appear to be autocorrelated in many of the specifications considered. Perhaps a relevant explanatory variable has been omitted. There is some evidence of a backward shift in supply from 1911–16 to 1917–22. However, the addition of tobacco or corn prices is not helpful. Walsh [8] considered the joint product aspects of cotton and cottonseed, but a variable taking account of cottonseed prices did not improve Walsh's results. Other possible sources of autocorrelation include misspecification of the functional form of the equation and the inclusion of irrelevant independent variables.

In summary, a change in the method of allowing for shifts in supply changes the conclusion about lagged responses. The author, of course, does not claim that the alternate equations, using zero-one variables and the Prices Paid deflator, are the "correct" alternatives, but in light of the varied results, one must reemphasize the importance and difficulty of fitting a valid model.

References

[1] Brandow, G. E., "A Note on the Nerlove Estimate of Supply Elasticity," *J. Farm Econ.* 40:719–722, Aug. 1958.

[2] Foote, Richard J., *Analytical Tools for Studying Demand and Price Structures*, Washington, USDA Agri. Handbook 146, Aug. 1958.

[3] Fox, Karl A., and D. Gale Johnson, eds., *Readings in the Economics of Agriculture*, Homewood, Ill., Richard D. Irwin, Inc., 1969.

[4] Koopmans, Tjalling C., "Identification Problems in Economic Model Construction," in *Studies in Econometric Method*, eds. William C. Hood and Tjalling C. Koopmans, Cowles Commission for Research in Economics Monograph 14, New York, John Wiley & Sons, Inc., 1953, pp. 27–48.

[5] Nerlove, Marc, "Estimates of the Elasticities of Supply of Selected Agricultural Commodities," *J. Farm Econ.* 38:496–509, May 1956.

[6] ———, *The Dynamics of Supply: Estimation of Farmers' Response to Price*, Baltimore, The Johns Hopkins Press, 1958.

[7] Strauss, Frederick, and Louis H. Bean, *Gross Farm Income and Indices of Farm Production and Prices in the United States, 1869–1937*, USDA Tech. Bull. 703, Dec. 1940.

[8] Walsh, Robert M., "Response to Price in Production of Cotton and Cottonseed," *J. Farm Econ.* 26:359–372, May 1944.

Economic Implications of Nonpar Delivery Points for The Live Cattle Futures Contract*

J. Richard Crow, John B. Riley, and Wayne D. Purcell

With variable intermarket price relationships between Omaha and the outlying market areas, the use of a single adjustment factor for nonpar delivery points will not significantly improve hedging opportunities. Using the Guymon (Oklahoma) point to illustrate, the need for more sophisticated adjustment procedures or consideration of separate contracts is demonstrated.

The Chicago Mercantile Exchange is decentralizing its delivery points for live cattle futures. In August 1971, Omaha replaced Chicago as the par delivery point with Guymon (Oklahoma) and Peoria (Illinois) as nonpar delivery points. The increase in number of nonpar delivery points emerges during a period characterized by questions about the viability of live cattle futures as a hedging mechanism. Surveys show little or no hedging by cattle feeders in Oklahoma [3]. Feeders are publicly voicing discontent with the performance of the futures market [2].

The economic role attributed to the futures market is to provide a mechanism by which the entrepreneur can transfer to others the risk associated with largely unpredictable cash price fluctuations. In a 1966 analysis of live cattle futures [4], Skadberg and Futrell adopted the premise that "to have economic merit, they (futures markets) must offer hedging potential or perform a valid pricing function." Trade in futures contracts for a particular commodity in any market is justified if such trade provides a mechanism for effective hedging.[1] The creation of nonpar delivery points should, therefore, increase either (1) the likelihood of an effective hedge or (2) the effectiveness of a hedge by increasing the ratio of reduction in risk to cost of the hedge.[2]

This analysis examines the Guymon delivery point as a viable contribution to hedging alternatives and considers the question of whether any nonpar delivery point can be expected to facilitate more effective hedging of cattle feeding activities.

Provisions for Delivery and Behavior of the Basis

Convergence of the cash and futures prices on or before the maturity date of the futures contract constitutes the basis for the much discussed "lock-in margin." ***The lock-in margin is not and cannot be guaranteed if there are no provisions for delivery.*** The possibility of delivery creates economic pressures which cause the basis to tend toward a magnitude equal to the cost of delivery under the futures contract.

The smoothness with which delivery can be completed determines the degree of convergence realized. Conditions complicating delivery will increase the costs associated with delivery, making the hedger hesitant to deliver and thereby increasing the magnitudes by which the two markets (cash and futures) are allowed to drift apart. When this occurs, the realized margin will not necessarily equal the lock-in margin.[3]

When the cattle are to be sold in a market area other than the par market, a "geographical basis" is calculated. The geographical basis is subtracted from the trading price for the futures contract to obtain an adjusted futures price. By then subtracting an estimated break-even price plus delivery and/or marketing costs, a lock-in margin can be calculated.

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[1] An "effective hedge" is defined as a hedge which reduces the monetary value that can be attributed to the risk of cash price fluctuations by an amount greater than the cost of the hedge.

[2] Focus on the hedging dimension is not meant to imply the nonpar delivery point will not affect related activities. In addition to playing a role in the price discovery process, a nonpar delivery point increases the quantity of cattle which could be delivered under futures contracts without being transported over long distances. Such an increase may reduce the likelihood a trader (or traders) can "squeeze" the contract to the extent price may be distorted up or down.

[3] Lack of convergence is to be expected when the maturity date of the contract does not coincide with the sales date on the cattle. The difference between lock-in margin and realized margin will be more variable for such hedges. This is true, however, regardless of the delivery point under consideration.

J. Richard Crow, John B. Riley, *and* Wayne D. Purcell *are research assistants and associate professor respectively in agricultural economics at Oklahoma State University.*

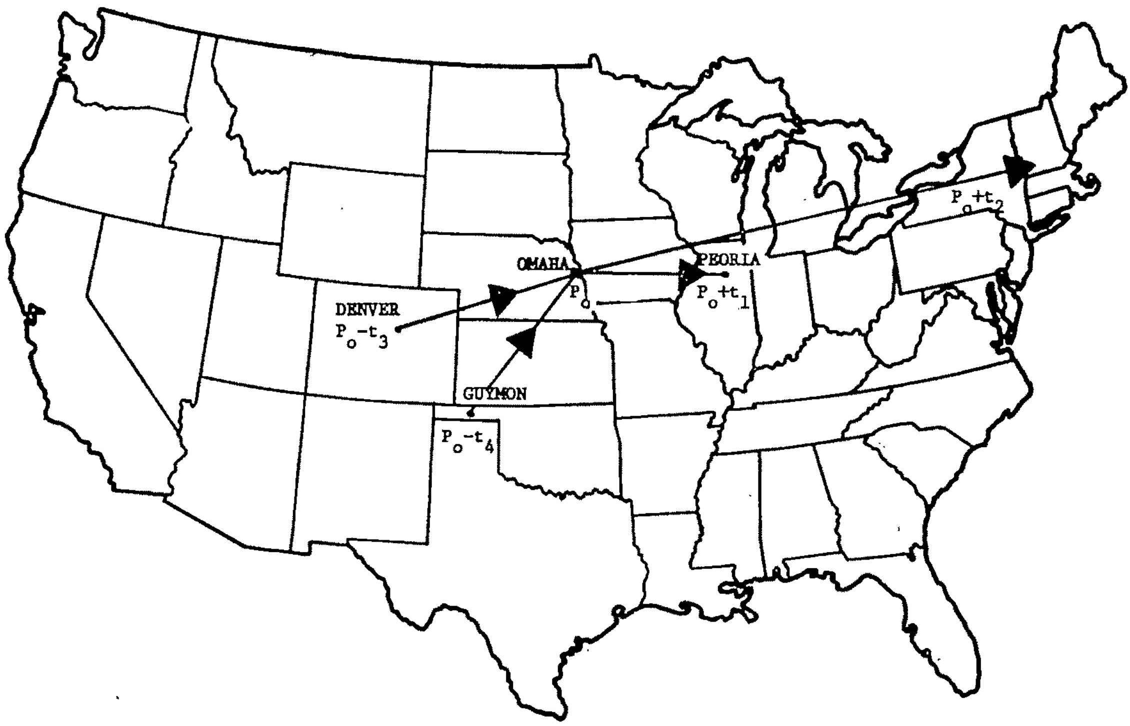

Figure 1. A theoretical basing-point price surface for beef (P_o=Omaha price, t_i=transportation cost)

The success of hedging efforts in any outlying area depends upon the degree of stability in the relationship between the cash price in that area and the futures price on the par delivery market. If this difference or "basis" is stable and therefore predictable with an acceptable degree of accuracy, the hedge can be effective. But it is the lack of such stability which has made effective hedging in the Guymon or other outlying areas difficult. The question of interest, therefore, is whether establishing a nonpar delivery point at Guymon or elsewhere will improve the situation.

Analysis

Nonpar delivery points have been established in a manner consistent with a basing-point price system. Prior to August 1971, delivery was possible in Omaha and Kansas City at discounts of $0.75 and $1.00, respectively, relative to Chicago. The Guymon point is being discounted $1.00 per cwt. relative to Omaha, which has replaced Chicago as the par market.

At least two important market areas now exist in the fed cattle industry. Consequently, the price relationships shown in Figure 1, relationships which coincide with the assumptions of basing-point pricing, do not hold today. The price in outlying market areas is *not* necessarily equal to P_o, the base price at Omaha, plus or minus a transportation cost t_i. Variability in the price differentials charted in Figure 2 lends support to the thesis that cattle fed in the Omaha and Guymon regions are in fact serving at least two different markets. The marketing channels for beef do not necessarily follow an eastward movement but follow paths similar to those pictured in Figure 3.[4]

If basing-point pricing does not exist, then an amount such as t_4 in Figure 1 is not appropriate as an adjustment for intermarket differences. The implications of using t_4 as an adjustment or discount fall roughly into the following categories:

1. If t_4 is greater than the "true" intermarket differentials, delivery would never be expected at the nonpar point.
2. If t_4 is less than the "true" intermarket differential, deliveries would tend to be

[4] The "paths" shown in Figure 3 are consistent with the optimal flows reported by Crom [1]. Interaction with trade people and packer personnel in the general Guymon area substantiate the flows shown in Figure 3. Any exceptions, such as the Guymon area packer shipping to the East Coast market, are rare and usually associated with an unusual slaughter and/or market arrangement.

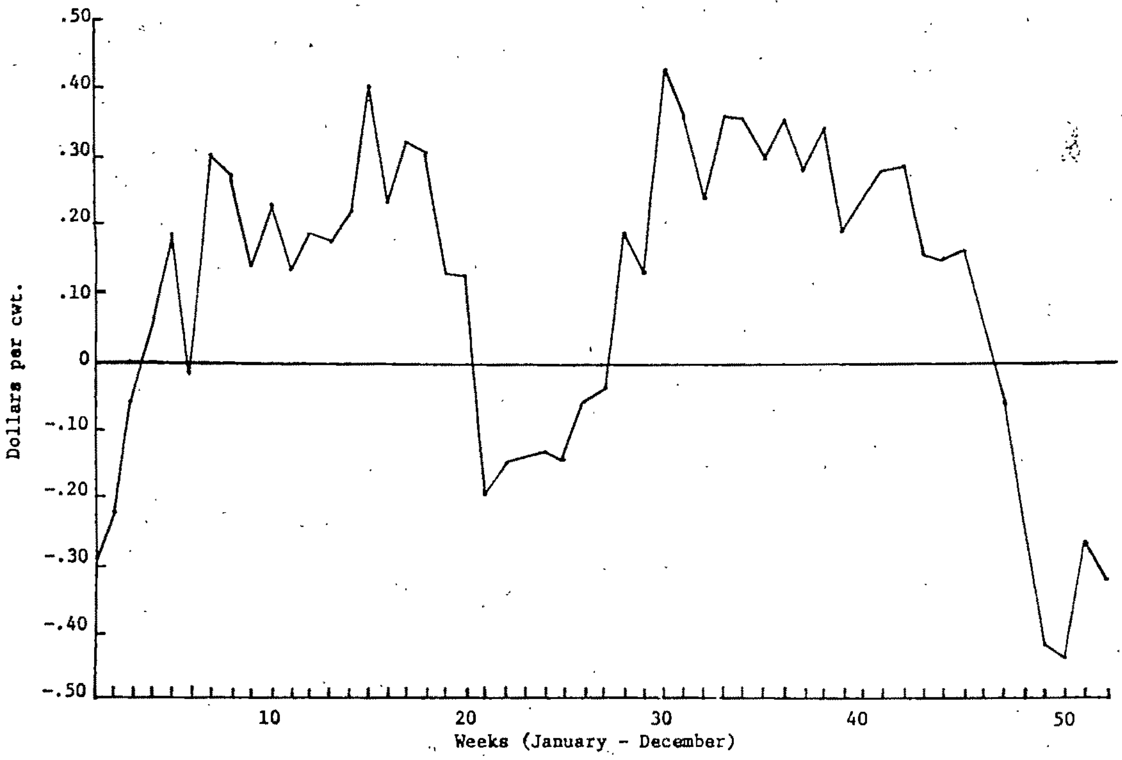

Figure 2. Cash price differentials, Omaha minus Clovis-Amarillo, 1967-1970 weekly averages

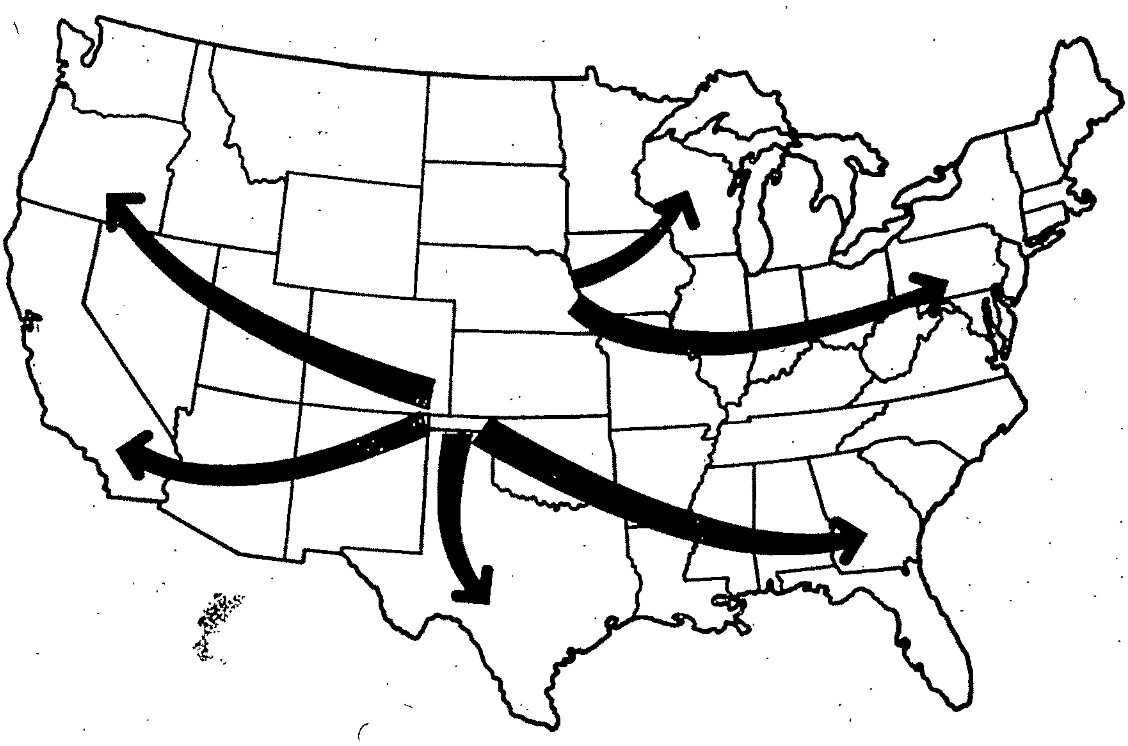

Figure 3. Estimated flow pattern of carcass beef, 1971

Table 1. Net outcomes from four alternative courses of action for the Guymon-area feeder: an illustration

Alternative courses of action	Net returns (losses) per cwt.
I. Complete hedge by selling on Guymon cash market and buying back futures contract.	\$1.57. . Using an estimated \$0.28 difference between Omaha futures and Guymon cash (\$0.18 +0.10), the feeder nets \$2.72 in the cash market, (\$1.00) in the futures market, and incurs a "cost of hedging" of \$0.15.
II. Delivery to Omaha by transporting the cattle to Omaha for delivery under the futures contract.	\$1.10. . Delivery at \$30.00, the costs incurred include the \$28.00 break-even cost, the \$0.15 "cost of hedging," and an estimated \$0.75 transportation cost to Omaha.
III. Deliver to Guymon by transporting the cattle to the Guymon market.	\$0.85. . Delivering at \$29.00, the costs incurred include the \$28.00 break-even cost and the \$0.15 "cost of hedging."
IV. Sell on cash in Guymon, buy cattle on cash in Omaha and deliver to Omaha.	\$1.60. . Using an \$0.18 Omaha futures-cash spread, a \$0.15 cost of buying cattle in Omaha, and a \$0.15 cost of trading futures the feeder nets (\$1.12) in the Omaha markets and \$2.72 in the Guymon cash market.

excessive at the nonpar point and would replace the normal market channels for the cash product.

The Guymon case: an illustration

Figure 2 pictures the price differentials between Omaha and the Guymon market area.[5] In the period 1967–70, the mean differential between the two markets (Omaha minus the Clovis-Amarillo series) was \$0.10 per cwt. The standard deviation of the differentials was \$0.38 per cwt. During the early summer and mid-winter months, the Clovis-Amarillo series typically moved *above* the price for comparable cattle at Omaha.

Consideration should be given the possibility the futures price at Omaha and the cash price at Omaha will not converge completely. An expected difference between the Omaha futures price and Omaha cash price can be estimated by considering past performance on the Chicago market. During 1967–70, the closing price for Chicago futures averaged \$0.18 per cwt. above Chicago weekly average cash prices with a standard deviation of \$0.42 per cwt.

Given this information, consider the situation confronting the feeder in the general Guymon market area. Table 1 traces the outcomes of four alternative courses of action by the feeder. The following assumptions were employed in developing Table 1:

1. The break-even cost, or price, is \$28.00 per cwt;
2. The relevant futures contract is trading at \$30.00 per cwt. when the cattle are placed and the hedge established; and
3. The futures contract is trading at \$31.00 per cwt. when the cattle are later sold.

The results of Table 1 indicate that feeders would consider courses of action in the following order or preference:

First, sell cattle on cash market in Guymon and buy cattle in Omaha for delivery in Omaha;

Second, sell the cattle and buy back the futures contract;

Third, deliver to the par-delivery market in Omaha; and

Fourth, deliver to the new nonpar point in Guymon.

The relationship among the four alternatives will hold regardless of price levels. In practice, the first alternative will probably be preferred to the fourth. The alternative of selling the cattle and then buying other cattle in Omaha for purposes of delivery exposes the feeder to higher levels of uncertainty and would be discounted for this reason.

Table 1 is oversimplified in one important respect: no consideration is given the costs of delivery under the futures contract. There are substantial costs associated with such delivery, costs estimated to range from \$0.50 to \$0.75 per cwt. at Chicago.[6] Experienced brokers indicate these costs will be roughly the same at Omaha, at Guymon, or at any other delivery point.

Incorporating this additional cost, however, does nothing to change the relationships shown in Table 1. If a value of \$0.50 is used to represent the delivery costs, the net return for each

[5] The price series used for the Guymon area is the series for 900–1100 lb. Choice steers currently reported from Amarillo. Prior to 1970, the series was reported from *Market News* offices located in Clovis, New Mexico.

[6] The costs are comprised of commission fees, yardage charges, feed and water, charges for grading by USDA graders, and an order-buying fee if, as is often the case, delivery is consummated by buying cattle on the market where delivery is to be made.

of the four courses of action is reduced by $0.50 per cwt. The reasons for the reductions are obvious for alternatives II, III, and IV. The reduction for Alternative I goes back to a previously stated thesis: any lock-in margin can be guaranteed only if the possibility of delivery is present. The costs of delivery must be deducted for planning purposes.

The establishment of the Guymon delivery point at $1.00 per cwt. under Omaha has done little to improve the hedging opportunities for the Guymon area feeder. The feeder will not consider contract delivery in *either* market until the cash price in the Guymon area falls at least $1.25 per cwt. below the futures price in Omaha. Such price relationships seldom, if ever, occur. Delivery to the *Guymon* market will be considered only when the differential in Omaha futures price and Guymon cash price equals at least $1.50 per cwt. ($1.00 discount plus $0.50 delivery cost).

Conclusions and Implications

The Guymon delivery point cannot be justified on the economic grounds considered in this study. Opportunities to hedge cattle feeding activities effectively in the Guymon feeding area were improved little if any by the establishment of the Guymon delivery point. On the basis of this analysis, a more general conclusion emerges: *Any nonpar delivery point which is established using the costs of moving the product to or from the par delivery point as a discount will be economically unsound if the implicitly assumed basing-point pricing system does not prevail.*

Examination of the intermarket price relationships between Omaha and the Guymon market area over the past four years suggests the two points are in related but geographically separate markets. The price relationships between the two markets have fluctuated within broad limits. Such fluctuations are not consistent with any basing-point pricing system and preclude the possibility of using any one discount to represent the intermarket differences. If effective hedging opportunities in each area is the goal, then either (1) separate contracts or (2) discounts which account for changing market interrelationships merit increased study and consideration.

References

[1] CROM, RICHARD J., *Simulated Interregional Models of the Livestock-Meat Economy*, USDA, ERS Ag. Econ. Rep. 117, June 1967.

[2] "Feeders Charge Traders Are Pushing Cattlemen Out of Live Futures Trade Market," *Beef* 7:14–15, April 1971.

[3] PURCELL, WAYNE D., AND TERRY L. DUNN, *Decision Processes of Oklahoma Cattle Feeders*, Okla. Agr. Exp. Sta. Bull. B-686, Nov. 1970.

[4] SKADBERG, J. MARVIN, AND GENE A. FUTRELL, "An Economic Appraisal of Futures Trading in Livestock," *J. Farm Econ.* 48:1485–1489, Dec. 1966.

Stepped Product Demand and Factor Supply Functions in Linear Programming Analyses*

NEIL R. MARTIN, JR.

Regional adjustment studies encounter less than perfectly elastic demand and factor supply conditions. Producing firms are assumed to face perfectly competitive markets. This paper reviews procedures for incorporating product demand and factor supply functions into linear programming analyses. Perfectly competitive conditions including industry income value are considered.

THE PURPOSE of this paper is to review procedures for incorporating stepped product demand and factor supply functions into linear programming (LP) analyses which assume perfectly competitive market conditions. The procedures are generally applicable to analyses of regional or national agricultural adjustments in which product supply responses and factor demand responses are generated endogenously, while product demand and factor supplies are treated as exogenous relationships. Throughout this paper, exogenous product demand and factor supply relationships will be referred to as demand and factor supply functions.

Three general procedures which have been developed to incorporate assumptions of less than perfectly elastic demand and/or factor supply functions in LP analyses are contrasted in this paper. Presented are a case supporting the superiority of these approaches when used to represent perfectly competitive conditions and alternatives for extending an associated computation.

Review of Three General Techniques

LP techniques will not permit consideration of all points on a less than perfectly elastic continuous demand or factor supply function. Past procedure has been to select a sufficient number of points on each function to obtain some desired level of precision and to use these price quantity points to construct stepped demand or factor supply functions.

Three general approaches have been followed to include stepped demand and factor supply functions in LP analyses. Procedures which include only one price quantity point from each stepped demand or factor supply function per run of the LP model will be referred to as *Approach I*. Studies using Approach I have generally made one price quantity change at a time along successive stepped demand or factor supply function [2, 5, 7]. Consecutive runs of these models have been made until equilibrium results or at least approximate equilibrium results were obtained.[1] This procedure produces results consistent with perfectly competitive conditions, but can require a large number of model computations before satisfactory results are obtained.

Two similar, yet different procedures—referred to as *Approach II* and *Approach III*—have represented several steps of demand and factor supply functions in single runs of LP models. These procedures permit the LP model to reach equilibrium solutions in much fewer model computations than would normally be required when using Approach I. Each step of each demand or factor supply function is represented by a column vector in the LP model. These column vectors are constrained by row vectors to be less than or equal to the quantities which are accounted for by the steps being represented. Approaches II and III differ only in terms of the prices or values placed in the objective function of the LP model. Approach III includes prices directly from the stepped demand and factor supply functions, while Approach II uses artificial prices in the objective function.

Studies using Approach II have pointed out that direct inclusion of demand or factor supply function prices in the objective function row of the LP framework will produce discrepancies

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NEIL R. MARTIN, JR. *is an agricultural economist with the Farm Production Economics Division, Economic Research Service, USDA, stationed at Urbana, Illinois.*

[1] By "equilibrium results" we refer to solutions in which all endogenous product supply levels and factor demand levels are equal to exogenous quantities demanded and supplied at a given set of prices.

between the objective function or income value and its theoretical value under perfect competition [1, 3, 6, 8]. Because the demand or factor supply vectors may enter the solution basis one at a time, the programming model will sell (buy) the highest (lowest) priced products (factors) first, before activating vectors representing lower (higher) priced steps on the demand (factor supply) functions. That is, demand (factor supply) activities with higher income (lower cost) will "dominate" the demand (factor supply) activities with lower income (higher cost). This property is presented in Yaron and Heady [10]. In moving through the successive demand (factor supply) vectors, the programming model will add to (subtract from) the objective function all the revenue (only the cost) under the stepped demand (factor supply) function rather than the revenue (cost) consistent with equilibrium price times equilibrium quantity.[2]

To avoid the above discrepancy, studies following Approach II have computed and used artificial prices for all but the first step of each demand or factor supply function [1, 3, 6, 8]. These artificial prices are calculated so that the weighted average price of any series of demand (factor supply) vectors will correspond to the demand (factor supply) curve price at the end of each step along the stepped functions. For example, if the stepped demand function is

$$(1.1)\qquad P = \begin{cases} P_1 & \text{if } 0 < Q \le Q_1 \\ P_2 & \text{if } Q_1 < Q \le Q_2 \\ \vdots & \\ P_N & \text{if } Q_{N-1} < Q \le Q_N \end{cases}$$

where $P_1 > P_2 > \ldots > P_N$ and $Q_1 < Q_2 < \ldots < Q_N$, the artificial prices or objective function values for demand vectors are computed by

$$(1.2)\qquad C_i = \frac{P_i Q_i - P_{i-1} Q_{i-1}}{Q_i - Q_{i-1}}, \qquad i = 1, 2, \cdots, N.$$

Similarly, the artificial prices for the stepped factor supply function

$$(2.1)\qquad K = \begin{cases} K_1 & \text{if } 0 < q \le q_1 \\ K_2 & \text{if } q_1 < q \le q_2 \\ \vdots & \\ K_n & \text{if } q_{n-1} < q \le q_n \end{cases}$$

where $K_1 < K_2 < \ldots < K_n$ and $q_1 < q_2 < \ldots < q_N$, are computed by

$$(2.2)\qquad D_i = \frac{K_i q_i - K_{i-1} q_{i-1}}{q_i - q_{i-1}}, \qquad i = 1, 2, \cdots, N.$$

The above procedure, as used in Approach II, will permit the objective function or income value to be consistent with all units of each product (factor) being sold (purchased) at one price which is approximately on the empirical stepped demand (factor supply) functions. However, the use of these artificial prices in the objective function will not insure that perfectly competitive equilibrium conditions are met. In fact, when Approach II is followed, monopoly and/or monopsony power is implied; that is, the added cost for which an additional unit can be produced may be less than the price for which that unit can be sold.[3] Similarly, the added value from an additional unit of a factor may be greater than the price for which that unit can be purchased. Therefore, the perfectly competitive condition [that in equilibrium the added cost for which and additional unit can be produced (purchased) must be greater than or equal to the price for which that unit can be sold (value derived from an additional unit)] may be violated. This implies monopoly (monospony) power to restrict output (purchase of inputs) [4].

Although studies using Approach III have not taken up the matter of implied monopoly and/or monopsony power when Approach II is followed, they do provide proof that perfectly competitive solutions can be obtained from LP

[2] This situation is consistent with the theory of a perfectly discriminating monopolist (monopsonist) facing a stepped demand (factor supply) function. Perfectly competitive assumptions would be violated in all cases except for model solutions on the first steps of all included demand and factor supply functions.

[3] This condition arises from the fact that artificial demand (factor supply) prices, as computed in Approach II, are less (greater) than the stepped demand (factor supply) function price when quantity sold (purchased) exceeds the quantity accounted for by the first step of the stepped function. Conditions for increasing output (input) in an LP model require that the objective function price must exceed (be less than) the marginal cost (value) of an additional unit. Therefore, when the demand (factor supply) function price exceeds (is less than) the objective function value at an LP solution output (input) level, the marginal cost (value) of an additional unit will very likely be less (greater) than the price for which that unit can be sold (purchased).

models of the type discussed above, if direct stepped function prices are used as objective function values in the demand or factor supply function activities [9, 10, 11]. The use of direct stepped function prices allows the LP model to reach its optimal solution when the added cost (value from) of an additional unit of output (input) is at least as great (low) as the price for which an additional unit can be sold (purchased). This LP solution will be consistent with perfectly competitive conditions in all but one aspect. The quantities of each commodity produced, the equilibrium price on each stepped demand function, the quantity of each factor used, and the equilibrium price on each stepped factor supply function will be consistent with perfectly competitive conditions. But, the income value in the objective function may be greater than the income value consistent with the perfectly competitive condition that all units of a homogenous product (factor) are sold (purchased) at its equilibrium price.[4] This fact was noted in the above discussion of Approach II. Given perfectly competitive results in every aspect except the income value, the remaining task in using Approach III is to determine the correct income value, assuming that income as well as quantity and price results are of interest in a given analysis.

To summarize the three general approaches, Approaches I and III can be used to obtain perfectly competitive equilibrium results and Approach II has an implicit assumption of monopoly (monopsony) power over the range of the stepped portion of each demand (factor supply) function included. Then Approaches I and III are both suitable for agricultural adjustment studies with the explicit assumption of perfect competition. In choosing between Approaches I and III, it should be noted that Approach III with an income correction can normally be expected to accomplish in less model computations any task that can be accomplished by Approach I.

Income Correction Procedures

At least three income correction procedures may be employed as additions to Approach III to get perfectly competitive income values and results comparable to those obtained by Approach I. Referring to equation (1.1), an amount equal to $[(P_1-P_2)Q_1+(P_2-P_3)Q_2+\ldots+(P_{j-1}-P_j)Q_j]$ can be subtracted by hand from the objective function value of an optimal solution obtained using Approach III in which the equilibrium price for this demand function is P_j at which quantity $[Q_1+Q_2+\ldots+Q_j]$ is sold. If the factor supply function given by equation (2.1) is also included and equilibrium price and quantity are K_h and $[q_1+Q_2+\ldots+q_h]$, respectively, the amount $[(K_2-K_1)q_1+K_3-K_2)q_2+\ldots+(K_h-K_{h-1})q_h]$ should also be subtracted from the objective function value obtained by Approach III. A similar hand calculation would then be made for each additional stepped demand and factor supply function included in the LP model.

Alternatively, the income adjustments given above could be handled by a computer report writing routine used in conjunction with the LP computations. This would avoid the necessity of hand calculations but require special computer programming instructions.

For those who prefer to avoid special hand calculations and special computer programming instructions in obtaining results through Approach III that are comparable with those obtained through Approach I, a third alternative is available. An efficient income correction procedure which may be employed as a part of Approach III is given in the partial matrix layout in Table 1. Column vectors 1, 2, and 3 represent a stepped demand function. Row vectors C, D, and E constrain demand vectors 1, 2, and 3 to be less than or equal to Q_1, Q_2-Q_1, and Q_3-Q_2, respectively. The objective function values P_1, P_2, and P_3 are in row A. These values are taken directly from the stepped demand function. Row B is an income accounting row which is designed to compute the corrected income value for the perfectly competitive "one price for all units sold" condition. Row B has P_1, P_2, and P_3 repeated for the demand

[4] If the LP model is structured according to Approach III, the solution results will be consistent with the theory of a perfectly discriminating monopoly/monopsony facing stepped demand and factor supply functions. Economic theory produces identical equilibrium results for both perfectly competitive industries and perfectly discriminating monopolies (monopsonies) that face the same demand (factor supply) and cost (value product) functions in every aspect except the industry income value. That is, both cases will increase quantity sold (purchased) until the added cost of (value from) an additional unit will be greater than or equal to (less than or equal to) the price for which an additional unit can be sold (purchased). The only theoretical difference between these two industry structures is that perfectly discriminating monopolies (monopsonies) will receive all (pay only) the revenue (cost) under the average revenue (outlay) curve, rather than equilibrium price times equilibrium quantity as in perfect competition [4].

Table 1. Partition of LP matrix to show structure for demand and factor supply functions and income correction technique

	Columns										Type of	
	1	2	3	4	5	6	7	8	9	10	constraint	RHS
Rows												
A	P_1	P_2	P_3	$-k_1$	$-k_2$	$-k_3$	t^a	t	t	t		
B	P_1	P_2	P_3	$-k_1$	$-k_2$	$-k_3$	$-(P_1-P_2)Q_1$	$-(P_2-P_3)Q_2$	$(k_1-k_2)q_1$	$(k_2-k_3)q_2$		
C	1.										$\leq$	Q_1
D		1.									$\leq$	Q_2-Q_1
E			1.								$\leq$	Q_3-Q_2
F				1.							$\leq$	q_1
G					1.						$\leq$	q_2-q_1
H						1.					$\leq$	q_3-q_2
I		$-m^b$					1.				$\leq$	0
J							1.				$\leq$	1
K			$-m$					1.			$\leq$	0
L								1.			$\leq$	1
M					$-m$				1.		$\leq$	0
R									1.		$\leq$	1
S						$-m$				1.	$\leq$	0
U										1.	$\leq$	1

[a] $t=1\div 10^N$, N being large enough so that column vectors 7, 8, 9, and 10 will not affect the level of any other activities in the optimal solution.

[b] $m=9(10^N)$, N being large enough to assure that m times the solution levels of column vectors 2, 3, 5, and 6 is at least as large as 1.

vectors from the objective function. Artificial column vectors 7 and 8 and artificial row vectors I, J, K, and L are structured to make corrections in the income row B while not otherwise affecting the optimal solution of the model. This is accomplished by constraining rows I and K to be less than or equal to zero, rows J and L to be less than or equal to one, and including a large negative coefficient in cells (2, I) and (3, K). A coefficient of one is included in cells (7, I), (7, J), (8, K), and (8, L), the coefficient $[-(P_1-P_2)Q_1]$ in cell (7, B), the coefficient $[-(P_2-P_3)Q_2]$ in cell (8, B), and very small positive values in the objective function row of vectors 7 and 8.

In this framework, vectors 7 and 8 add to the objective function which is being maximized but not by a number large enough to change the optimal solution. Vector 7 (vectors 7 and 8) will enter the solution at any time vector 2 enters (vectors 2 and 3 enter) the solution. Furthermore, vectors 7 and 8 will either be in the solution at a level equal to one or not in the solution at all. This process makes an exact income correction on all units sold by vector 1 (vectors 1 and 2) when the model sells any units by vector 2 (vector 3).

Column vectors 4, 5, and 6 represent a stepped factor supply function. Row vectors F, G, and H constrain supply vectors 4, 5, and 6 to be less than or equal to q_1, q_2-q_1, and q_3-q_2, respectively. The objective function values for these factor supply vectors are taken directly from the stepped factor supply function. Artificial column vectors 9 and 10 and artificial row vectors M, R, S, and U are structured to make income corrections in row B, while not otherwise affecting the optimal solution of the model.

Summary

Agricultural adjustments studies often involve the use of LP models, the representation of exogenous demand and/or factor supply functions, and the assumption of perfectly competitive markets. Stepped functions have been used to approximate continuous demand or factor supply functions in these models.

Several studies have demonstrated the inclusion of stepped demand and/or factor supply functions in aggregate LP analyses. These studies can be classified as either Approach I, II, or III. Approach I techniques normally require a large number of computations before equilibrium results are obtained. This approach becomes less feasible as the overall size of an LP model becomes large. Approach II is applicable to studies that assume monopoly or monopsony power within the subsector being analyzed but is not generally suitable to studies that assume perfectly competitive markets. The LP model suggested in this paper (Approach III) is somewhat a combination of Approaches I and II. Like Approach II, entire stepped demand func-

tions are included in a single computation of the model. This allows an equilibrium solution to be reached in one or two model computations. Unlike Approach II and more like Approach I, direct stepped demand and factor supply function prices are included in the objective function, rather than the artificial prices as used in Approach II. Optimal solutions from this proposed technique are consistent with perfectly competitive conditions in every aspect except the objective function or income value, which will usually be greater than the income value consistent with one price for all units of homogenous products sold or factors purchased.

Approach III in conjunction with the internal income correction technique is readily applicable to standard LP computer programming and requires no special computer programs or hand calculations. This procedure, including the income correction technique, represents an LP model framework which is capable of including several steps of a single demand or factor supply functions and more than one stepped function in a single computation of an aggregate agricultural adjustments LP model. Optimal solutions obtained from this approach will be consistent with perfectly competitive equilibrium conditions.

References

[1] ALDUNATE, PAUL, "Labor and Capital Sectoral Allocation in the Chilean Economy: A Linear Programming Macro-Economic Model," unpublished Ph.D. thesis, Purdue University, 1967.

[2] BAKER, C. B., "Evaluation of Economic Models Used in Regional Aggregate Studies," in *Price and Income Policies*, Series 17, Raleigh, Agricultural Policy Institute, North Carolina State University, April 1965, pp. 71–81.

[3] BERRY, JOHN H., "A Method for Handling Pecuniary Externalities in Relating Firm and Aggregate Supply Functions," unpublished Ph.D. thesis, Purdue University, 1969.

[4] DUE, JOHN F., AND ROBERT W. CLOWER, *Intermediate Economic Analysis, Resource Allocation, Factor Pricing, and Welfare*, 4th ed., Homewood, Illinois, Richard D. Irwin, Inc., 1961.

[5] HENRY, WILLIAM R., AND ROBERT RAUNIKAR, "Stepped Function Models," in *Interregional Competition; Research Methods*, Series 10, ed. Richard D. King, Raleigh, Agricultural Policy Institute, North Carolina State University, 1963, pp. 69–77.

[6] HILL, LOWELL D., *Agricultural Market Planning in Resource Development*, Univ. Ill. Coll. Agr. Special Publication 9, Dec. 1965.

[7] SKOLD, MELVIN D., AND EARL O. HEADY, *Regional Location of Production of Major Field Crops at Alternative Demand and Price Levels, 1975—A Linear Programming Analysis*, USDA Tech. Bull. 1354, 1966.

[8] WORDEN, GAYLORD E., "An Interfirm Competition Model for Deriving Empirical Estimates of Supply Response," unpublished Ph.D. thesis, Iowa State University, 1970.

[9] YARON, DAN, "Application of Mathematical Programming to National Planning in Agriculture," *The Farm Economist* 10:256–264, 1963.

[10] ———, AND EARL O. HEADY, "Approximate and Exact Solution to Non-Linear Programming Problem with Separable Objective Function," *J. Farm Econ.* 43: 57–70, Feb. 1961.

[11] ———, YAKIR PLESSNER, AND EARL O. HEADY, "Competitive Equilibrium-Application of Mathematical Programming," *Canadian J. Agr. Econ.* 13:65–79, 1965.

Break-Even Analysis: A Practical Tool In Farm Management

RUSSELL L. BERRY

Break-even charts provide managers with a simple method for exploring a range of production possibilities for a given farm plant. The charts may also help the manager evaluate machinery combinations and plant sizes.

THIS ARTICLE proposes to explain how break-even charts can be used to expand the results of a budget for a "fixed" farm plant to the entire range of its production possibilities and to explore the economies of various plant sizes.[1]

Following Carter and Dean [4, p. 268], machinery and equipment are considered fixed and and variable. Most farm operators must meet certain living expenses, having sacrificed most alternative employment opportunities when they decided to farm. Hence, that part of the operator's labor devoted to crops is considered fixed in these examples, even though his time will have to be reallocated as the size of the farm increases.

Break-Even Analysis Explained

Economic theory suggests that costs change gradually as plant output expands, and hence may be presented graphically as curved lines [5, pp. 91, 322]. Since these theoretical costs curves are readily available in economics textbooks they will not be reproduced here. Break-even analysis presents conventional plant cost curves in unconventional linear form because yields, prices, and costs are assumed constant in the "relevant range" of plant capacity. While this linear assumption can be questioned, plant scientists and economists still find it practical to assume there are "no loss" periods for planting, cultivating, and harvesting crops. Costs of inputs and price of output are also usually held constant. Thus, it is assumed that when operations can be completed within these periods, an increase in crop acres or output will not result in either higher unit costs or lower prices [3, 4, 7, 8, 9, 14]. Stated differently, it is assumed that costs and returns are linear within a certain range—the relevant range of break-even charts.

[1] The reader is referred to Moore and Jaedicke [11], the National Association of Accountants [12], and Spencer [13] for general literature dealing with break-even or cost-volume-profit analysis.

RUSSELL L. BERRY *is associate professor of economics at South Dakota State University.*

Conventional textbook cost curves usually show physical output on the horizontal axis and costs and returns relevant on the vertical axis. This is also true of conventional break-even charts. But because a typical farm plant usually produces a "mix" of several crops, the output must be measured either in dollars or by some other means. When both the crop mix and yields are assumed constant in the relevant range, the output on the horizontal axis can be measured in acres as shown in Figures 1, 2, and 3. The use of acres permits costs and returns per acre to be shown on the vertical axis (Fig. 3). This is a practical advantage for farm managers who are accustomed to thinking of costs and returns on a per-acre basis.

The most commonly used form of break-even chart is shown in Figure 1. Costs and returns used in this chart are those of a hypothetical one-man farm operated with four-row machinery developed by Van Arsdall and Elder [14]. For this farm total fixed costs (TFC) were estimated to be \$10,200. Of this amount \$3,300 was fixed machinery costs, \$5,400 the operator's fixed labor costs, and \$1,500 for buildings and equipment. Average returns from the crop rotation or "mix" were \$113 and average variable costs \$61 an acre, making net cash returns \$52 an acre. To draw the chart, all that is necessary is to establish the total costs (TC) and total return (TR) for some specific acreage (this is most easily done for 100 acres) and draw straight lines through these points as shown (Fig. 1). This break-even chart differs from conventional total cost and return curves in that both TC and TR are linear and output is measured in acres. Because TFC do not change they would be represented by a straight line in either case.

The acres of output needed to achieve any given profit can be read direct from the chart or calculated using this formula:

$$\frac{\text{Total fixed costs} + \text{profits}}{\text{Total returns} - \text{variable costs}} = \text{Acres of output.}$$

For example, the break-even point (zero profit) of Figure 1 is

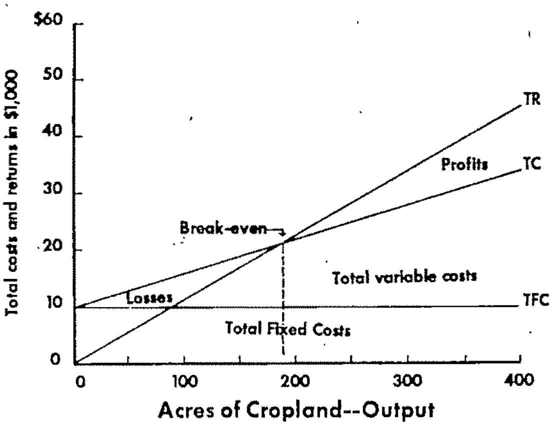

Figure 1

$$\frac{\$10,200 + 0}{\$113 - \$61} = \frac{\$10,200}{\$52} = 196 \text{ acres.}$$

Obviously to be practical, all break-even charts must be based on data from a budget. This may be either a first approximation or a final master budget, either partial or complete. If livestock is produced and only crops are considered, as is the case here, then a partial budget is used. The value of the break-even chart depends on the quality of the budget and the care with which the relevant range is established. However, one advantage of the break-even chart is that it can quickly show the implications of rough estimates, thus challenging the farmer to produce better data for revision. The break-even charts are simple enough for many farmers to make their own analyses.

Livestock are not included in this analysis since they usually require a separate plant with their own fixed building, machinery, and labor costs. Livestock should often have their own break-even chart. The larger and more important the enterprise the more reason for separate treatment. This is especially true of livestock ranches, dairy farms, and specialties such as egg, broiler, pork, and beef operations. However, when a livestock enterprise such as hogs or fat cattle varies in size directly with grain or hay production, or when a herd of beef cows or ewes varies with pasture available, such livestock enterprises can be handled as part of the mix. This was done by Ihnen and Heady [9] when they assumed that the size of a beef cow herd varied directly with the size of the farm. What is needed is more study of break-even charts for livestock enterprises, which are often complementary or supplementary to field crop production. Hence, the analysis needs to take these special relationships into consideration.

Using the same costs and returns, the break-even chart shown in Figure 1 can be reduced to the two-line break-even chart of Figure 2. To do this, the "contribution to profits" made by each unit produced was determined by subtracting the average variable costs ($61) from the average gross returns ($113). The result, $52 total net cash returns (TNCR) per acre, becomes the "profit line." The point where this line cuts the total fixed cost line should give the same break-even acreage or output (compare Figs. 1 and 2).

These two break-even charts place heavy emphasis on sales (TR), as they should for any firm selling in imperfect markets where salesmen, service, and advertising are important. If sales are assured, a small firm can usually buy the additional materials and hire the additional labor to produce the product. In contrast, the farmer can sell all he can produce at the going market price except where limited by government regulations. His problem is to secure the land and labor to expand output. He must spread his high fixed costs for machinery and labor over enough acres of cropland to lower costs to the point where he can make a profit. A break-even chart emphasizing this problem is needed and can easily be prepared by using average costs and returns per acre. Instead of totals as used in Figures 1 and 2, the same data are shown as averages in Figure 3 where more emphasis is placed on the average fixed cost (AFC) curve and less on average net cash returns (ANCR), defined as gross returns less variable costs per acre. Points for the AFC curve can be determined by dividing total fixed

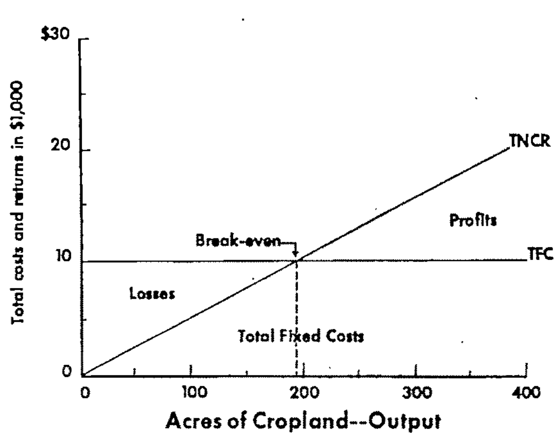

Figure 2

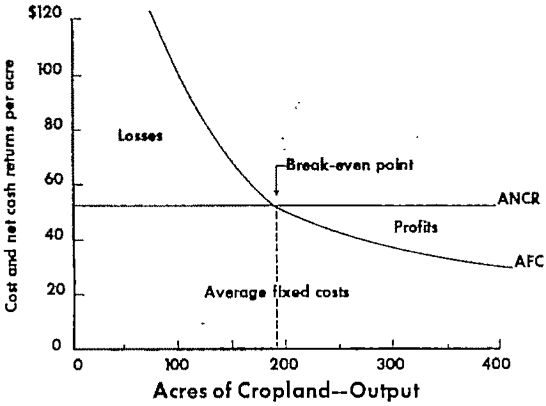

Figure 3

costs by three or more outputs (acres). Once these points are located, the curve can be drawn with a French curve or even freehand. In Figure 3 every time output is doubled, the average fixed cost per unit or acre falls by half. Moreover, average fixed costs fall more rapidly at first, declining more and more slowly as output increases. Because these characteristics of fixed costs are of great importance to farmers, especially those with small farms, this kind of break-even chart has much to recommend its use in farm planning.

Farm management specialists have been using a chart similar to the one in Figure 3 to illustrate the break-even point between ownership and custom hire of combines, balers, and other large equipment [6, 10]. The author has used break-even charts such as Figure 3 in two previous articles [1, 2].

Heady with colleagues Ihnen [9, Fig. 2], Krenz [7, Fig. 2], and McKee and Haver [8, Fig. 9] has used figures similar to Figure 3 in studies of farm size. Their curves differ in that they show average *total* costs per acre and do not subtract average variable costs from average revenue as was done in Figure 3. Nevertheless, all that is needed to convert their figures into break-even charts is a horizontal line indicating total returns per acre for the crops grown. This returns line could turn downward with decreasing yields beyond the no-loss period. But these research workers in their final charts chose to reflect the decrease in yields in their cost curves, so that when yields begin to fall, costs per unit start to rise, thus revealing the least cost points on the curves. The resulting charts are conventional unit cost curves. But even these curves can be used as break-even charts. For example, Van Arsdall and Elder [14] present in Figure 4 the same data used in Figures 1, 2, and 3. Until the least-cost cost point is reached, there should be no difference between the curve presented in Figure 3 and Figure 4, inasmuch as the fixed costs are the same and the variable costs are constant until the yields begin to fall starting at the least cost point. Obviously this least cost point is important to farmers, especially those with very small or very large acreages.

When using break-even charts, the end of the relevant range to the right of the least cost point can be adequately determined by the capacity of various machinery combinations, days available for crop work, and effect of delays on yields, quality, and prices. Research is needed to determine the effects of these factors on the relevant range. The end of the relevant range can be indicated by a vertical line on the break-even charts. Or, if preferred and information is available, a decrease in yields can be indicated by the gradual fall of the total returns line in Figure 1 and by a similar fall in the net cash return lines of Figures 2 and 3. While the costs per acre on these charts would not change, least cost acreage or output would still be clearly indicated by the maximum vertical distance between the cost and return lines of the charts.

Economies of Plant Size

As a farm plant consisting of "fixed" machinery and labor expands its output or acreage, questions soon arise about the economies of plant size. Are more or larger tractors needed? Should a change be made from 4-row to 6-row or 8-row machinery? Would a two-man, a three-

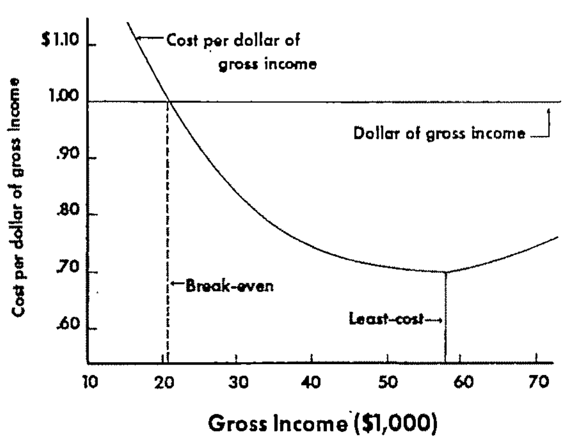

Figure 4

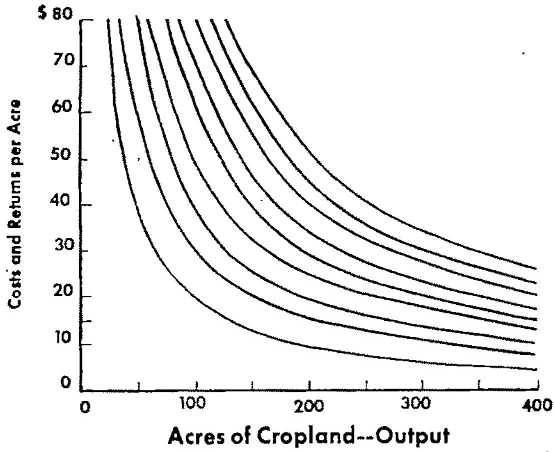

Figure 5

man, or an even larger farm be more profitable? These and other questions relating to size can be handled by a chart showing average fixed costs for a range of plant sizes (Fig. 5). In this example the *total* fixed costs for the nine plants range from $2,000 to $10,000 by $1,000 increments. (For farms with total fixed costs of $12,000 or more the figures on the vertical scale can be doubled.) Such a worksheet permits the manager to choose the ready-made AFC curve that represents his present situation and color code it for easy identification. When yields and net cash returns begin to fall due to untimely crop operations, the manager can use such a worksheet to explore the possibilities of enlarging his plant (shifting to higher AFC curves) to prevent the decrease in yields and to increase profits.

As changes are made in plant size, changes in the management input may be needed to maintain the level of net cash returns. Also, as Carter and Dean [4] have indicated, changes in the mix of crops may be necessary because of soil differences, diseases, contract limitations, government regulations, and risks. These adjustments are needed regardless of the method of analysis used and can be easily explored using break-even charts. In using break-even charts the total returns or net cash returns should reflect the average yields that can be expected for the plant size. The uncertainties of yields will increase as acreage is expanded to the full capacity of the plant. The larger the plant the greater the uncertainties are likely to be.

Summary and Conclusions

The main purpose of this article is to explain how break-even charts can be used to expand a single budget for a "fixed" farm plant into its entire range of production possibilities for which yields, costs, and prices can be assumed to be constant or linear (the relevant range). The article also briefly explains how the break-even charts can be used to study the economies of plant size. The break-even charts are the same as conventional cost curves except that they are in unconventional linear form. Since it is assumed that crop mix, yields, and prices do not change within the relevant range, output can be expressed in acres rather than bushels or dollars of output. This use of acres makes it easier to obtain the needed data and easier for farmers to understand since they already think of costs and returns on an acre basis. In these charts the entire crop rotation or mix is analyzed as if it were one crop. This technique avoids cost accounting problems of allocating costs among complementary, supplementary, and competing crops produced by the same machinery and labor. Separate break-even analyses will be needed for major livestock enterprises.

One advantage of the charts is that they are easier and less costly to use than budgets, linear programming, and electronic data processing. Perhaps a more important feature is that they clearly emphasize the reason why most small farms are being consolidated into larger ones—high fixed costs due to too few acres of output to break-even. The need to break even and the extra profits to be made by exceeding the break-even point should challenge most farm managers to seek ways to spread their high fixed costs for machinery and labor over more acres or output and maintain or increase their average net cash returns. This challenge of the chart may be its most important advantage.

References

[1] BERRY, R. L., "How Many Acres Do You Need To Break Even?" *Dakota Farmer* 81:12, Dec. 9, 1961.
[2] ———, "More Acres Can Cut Fixed Costs," *Farm Quarterly* 17:82–83, 1962.
[3] CANDLER, WILFRED, MICHAEL BOEHLJE, AND ROBERT SAATHOFF, "Computer Software for Farm Management Extension," *Am. J. Agr. Econ.* 52:71–80, Feb. 1970.
[4] CARTER, H. O., AND G. W. DEAN, "Cost-Size Relationships for Cash Crop Farms in A Highly Commercialized Agriculture," *J. Farm Econ.* 43:264–277, May 1961.

[5] HEADY, EARL O., *Economics of Agricultural Production and Resource Use,* Englewood Cliffs, N. J., Prentice-Hall, Inc., 1952.

[6] ———, AND HARALD R. JENSEN, *Farm Management Economics*, New York, Prentice-Hall, Inc., 1954.

[7] ———, AND RONALD D. KRENZ, *Farm Size and Cost Relationships in Relation to Recent Machine Technology. An Analysis of Potential Farm Change by Static and Game Theoretic Methods*, Iowa Agr. Exp. Sta. Res. Bull. 504, May 1962.

[8] ———, DEAN E. MCKEE, AND C. B. HAVER, *Farm Size Adjustments in Iowa and Cost Economies in Crop Production for Farms of Different Sizes*, Iowa Agr. Exp. Sta. Res. Bull. 428, May 1955.

[9] IHNEN, LOREN, AND EARL O. HEADY, *Cost Functions in Relation to Farm Size and Machinery Technology in Southern Iowa*, Iowa Agr. Exp. Sta. Res. Bull. 527, May 1964.

[10] LOFTSGARD, LAUREL D., DALE O. ANDERSON, AND MARVIN T. NORDBO, *Owning and Operating Costs for Farm Machinery*, North Dakota Agr. Exp. Sta. Bull. 436, Sept. 1961.

[11] MOORE, C. L., AND R. K. JAEDICKE, *Managerial Accounting*, 2nd ed., Dallas, South Western Publishing Co., 1967.

[12] National Association of Accountants, *Analysis of Cost-Volume-Profit Relationships*, New York, 1950.

[13] SPENCER, M. H., *Managerial Economics*, 3rd ed., Homewood, Ill., Richard D. Irwin, Inc., 1968.

[14] VAN ARSDALL, ROY N., AND WILLIAM A. ELDER, *Economics of Size of Illinois Cash-Grain and Hog Farms*, Ill. Agr. Exp. Sta. Bull. 733, Feb. 1969.

Concave Programming Applied to Rice Mill Location*

Wilfred Candler, James C. Snyder, and William Faught

This paper provides an intuitive discussion of a concave programming algorithm capable of eventually reaching a global optimum. Two local optima are reported for a concave programming problem with 427 restraints, 4089 linear transportation activities, and 16 non-linear falling average cost milling activities.

This paper illustrates the use of concave programming to find a locally optimum (least cost) mill configuration for the U.S. rice industry.[1] This involves problems of optimization under conditions of falling average cost, and hence, the development of a non-linear programming algorithm. This paper briefly reviews the nature of the falling average cost problem, indicates one approach to its solution, and finally provides some gross statistics on the local optima for the milling industry found in this study.

Previous examples of plant location problems with falling average cost have been published by King and Logan [3] and Stollsteimer [6]. The present study differs from both of these in that three raw materials instead of one had to be processed into four, rather than one, final products. Hence, the previously employed transshipment model could not be used.

The rice mill location problem was too big to allow full enumeration of plant site possibilities as illustrated by Stollsteimer [6]; moreover, it involved automation of the partly heuristic procedure used by King and Logan [3]. An algorithm was developed, utilizing Tui's ideas [8], to allow orderly examination of more than one locally optimum set of plant locations.

The rice mill locational problem considered in this paper involved the least cost allocation of three types of rice (long, medium, and short) from 49 dryers to 16 mills, where it was converted into four products for distribution to 66 final markets. Collection, processing, and distribution costs were considered in the study. After the deletion of impossible and very expensive alternatives, this resulted in a problem with 427 restraints and 4137 activities of which the 16 milling activities had non-linear costs.[2]

It was assumed that all 16 mills had the same non-linear cost function

$$TC = 1032.422Q \qquad 0 \leq Q \leq 50$$

$$TC = Q(233.637 + (1357.136/\text{Log}_{10} Q)) \qquad 50 < Q$$

where:

TC is total cost in dollars and
Q is annual quantity milled in 1000 cwt.

Average cost is

$$AC = 233.637 + (1357.136/\text{Log}_{10} Q) \qquad 50 < Q$$

which is a *declining* function of quantity but declines at a declining rate.

Raw rice availability and final product demands were assumed to be fixed. The industry was not assumed to involve supply and demand functions; rather, supply and demand were taken as being predetermined. The focus of the problem was, given these quantities, how would transportation and milling costs be minimized?

Concave Programming

The rice milling problem can be regarded as a particular example of a much wider range of concave programming problems.[3] The concave

* The plant location algorithm reported in this paper was developed under Project 1595 of the Purdue Agricultural Experiment Station; the example of an application to rice milling draws on work carried out for the Fibers and Grains Branch of USDA. With the usual caveat, the authors wish to express their appreciation to Dale Shaw for a very searching reading of an earlier draft of this paper. Journal Paper No. 4586, Purdue Agricultural Research Station, Lafayette, Indiana.

[1] Since a review of plant location studies has appeared recently in the AJAE [7], it will not be duplicated here.

Wilfred Candler *and* James C. Snyder *are professors of agricultural economics at Purdue University and* William Faught *is chief of the USDA Fibers and Grains Branch, Washington.*

[2] A full description of the problem and its solution is being prepared for publication by the Fibers and Grains Branch, ERS, USDA.

[3] We are here concerned with the *minimization of a concave function* subject to linear inequalities [8]. In contrast to linear programming, a local optimum is not necessarily global; there may be many local optima. ***Minimizing a concave function*** is mathematically equivalent to ***maximizing a convex function***. In contrast, the ***maximization of a concave function***, subject to linear inequalities ensures that a local

programming problem can be written: find a non-negative n-vector x such that

$$z = F(x) \quad \text{a minimum}$$

$$\text{subject to} \quad Ax \leq b$$

$$x \geq 0$$

where:

A is a $m \times n$ matrix,
b is a $m \times 1$ vector, and
$F(x)$ is a concave function, with the property:

$$F((1-\sigma)x + \sigma y) \geq (1-\sigma)F(x) + \sigma F(y); \quad 0 \leq \sigma \leq 1$$

where y is any other n-vector.

This means that the function F lies on or above a chord between any two points on the function. As an example, in this particular case the total cost of milling 500,000 cwt. ($368,235) is more than ($343,008), which is the average of the total cost of milling 0 ($0) and 1,000,000 cwt. ($686,015).

Exactly the same sort of linear restraints as are used in linear programming apply to concave programming. It is the form of the objective function which distinguishes concave from linear programming.

The most significant consequence of a concave objective function is that there may be, and usually will be, ***many local optima.*** That is to say, there will be many solutions, each of which is better than any other solution in its immediate neighborhood.

The general nature of the concave programming problem is shown in Figure 1. This figure has x_1 and x_2 on the axes (say throughput of Mills 1 and 2), three restraints, DE, EF, and FG, and the contours of the objective function. The aim is to ***minimize*** the value of the objective function, so one local optimum obviously occurs at A. The feasible area for the original problem is $ADEFG$.

Point A in Figure 1 ($x_1 = x_2 = 0$) refers to a solution where plants 1 and 2 are not being used; variables x_1 and x_2 are non-basic. This is a

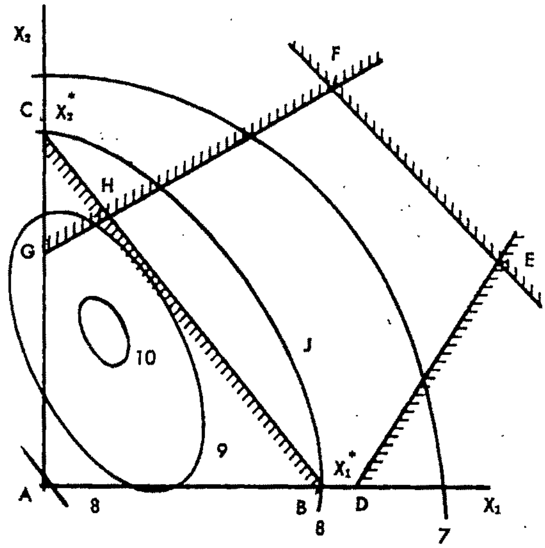

Figure 1. General Nature of Concave Programming Problem

feasible solution, however, since other plants are operating at positive levels. The segment AB involves increasing the throughput of plant 1 (and hence decreasing the throughput of some other plant, not shown in the figure). Segment DE represents a complementary relationship between plants 1 and 2, possibly due to plant 1 being able to meet market requirements for only one product, if other requirements in the market are met from plant 2.

Assuming local optimum A has been found, and if $x_2 = 0$ (Mill 2 remains closed), then there is no lower cost solution unless $x_1 \geq x_1^*$ at B. If $x_1 = 0$ (Mill 1 remains closed), then there is no lower cost solution unless $x_2 \geq x_2^*$ at C. A line ("insert a cutting plane") BHC can be drawn which excludes only solutions with a higher value than at A. Of course, if one knew how to handle non-linear restraints, he could use the 8-contour BJC as a restraint. However, this is not known.

It is a feature of a concave function that if the function has value 8 at A, B, and C, it will have value 8 *or more* between A, B, and C; hence, it is apparent no solutions better than A have been excluded. The algebraic form of the restraint in Figure 1 is

$$x_1/x_1^* + x_2/x_2^* \geq 1.$$

With this cutting plane in use, the feasible space is $BDEFH$, and solving this new problem will be restricted to solutions which lie inside this smaller solution space.

optimum is global. This latter problem has also been described in the literature as concave programming [2,4]; unfortunately, convex programming has also been used to describe the solution of problems where any local optimum is global [5]. The terminology of non-linear programming will remain confusing until a convention is established to regard all nonlinear programming problems as maximization, or as minimization problems.

Locating a Local Optimum

To find a local optimum, such as A in Figure 1, a series of linear programming problems is solved, as discussed previously by King and Logan [3]. Starting with some feasible solution, x^{k-1}, a gradient vector is defined incorporating the marginal processing costs evaluated at the solution, x^{k-1}

$$c^k = [F'(x^{k-1})] \tag{1}$$

and using c^k to give a linear objective function $c^{k'}x$ for the kth linear programming problem. The optimum solution to the kth problem is then inserted into (1) to give a new objective function for the $(k+1)$th problem and so on, until no further small improvement in x can be made.[4]

A Lower Bound to Mill Cost

In the rice mill location study only 16 sites were considered. Even after elimination of infeasible and "very expensive" transportation routes, there were 4089 transportation activities with normal linear costs in the objective function.

By ignoring mill cost, i.e., assuming all mills had zero milling costs, a minimum feasible annual transportation (collection and distribution) cost of $132.28M was found. By then assuming that the total rice volume went through mills corresponding to the largest volume at the local optimum, "minimum" milling costs of 54.22 cents per cwt., or total annual milling costs of $40.28M, were obtained. Thus, it could be concluded that milling and transportation costs could not be less than $172.56M. This gave an approximate lower bound on the value of the objective function.

Cutting Plane

An intuitive explanation of the cutting plane has been given above, and a rigorous treatment is available in [8]. A numerical example of the calculation of the minimum change in plant throughput required for an alternative solution may be helpful. Looking at Figure 1, it is assumed that there is a solution such as A with two plants operating at zero level. Suppose one of these is at Jonesboro, Arkansas, and the local optimum is solution 5 in Table 1. Further, suppose Jonesboro has a transportation advantage of 10¢/cwt. This transportation advantage is the saving that could be made in rerouting rice shipments if a *small* quantity of rice could be milled at Jonesboro without changing total milling costs.[5]

The transportation advantage is an estimate, actually an upper bound,[6] of the transportation cost reduction due to reallocating rice to Jonesboro from the locally optimum allocation listed as solution 5 in Table 1.

This change in transportation cost (in dollars) in this example has been estimated as[7]

$$\Delta TC = -100x_2$$

where x_2 is quantity milled at Jonesboro in 1000 cwt.

The minimum increase in milling cost is given by

$$\Delta MC = TC_2(x_2) + TC_1(x_1^* - x_2) - TC_1(x_1^*) \tag{2}$$

where $TC_i(x)$ is the total milling cost at plant i with a throughput of x_i, 1000 cwt., and $x_i^* = 967$ is the locally optimum throughput (solution 5) for the highest (marginal) cost, active, plant (Louise, Texas).

For $x_2 \leq 50$, equation (2) can be written

$$\begin{aligned}\Delta MC = {} & 1032.44x_2 + (967 - x_2)(233.637) \\ & + (1357.136/\mathrm{Log}_{10}\,(967 - x_2))) \\ & - 967(233.637 + (1357.136/\mathrm{Log}_{10}\,967)); \\ & \qquad 0 \leq x_2 \leq 50.\end{aligned}$$

The corresponding estimated change in total cost is

$$\Delta TTC = ATC + \Delta MC$$

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[4] This is essentially the same procedure as that used by King and Logan [3]. The major differences are (1) the present study was fully computerized so that there was no hand adjustment process and (2) as a result, heuristics of the type used by King and Logan were not used. In addition, the present study substituted marginal rather than average costs in the definition of revised problems. A proof of convergence to a local optimum is offered in [1].

[5] In fact, total milling costs would be adversely affected by such a small change: (1) The rice milled at Jonesboro would cost 103.24¢/cwt. in direct cost, and (2) at least one other mill would be forced to operate at a lower volume so that its average cost per cwt. would rise.

[6] It is an upper bound to saving, since it is calculated on the basis of the most advantageous rerouting of rice. When all rice available for this particular routing has been used, transport costs will tend to rise and the location advantage will tend to fall.

[7] The transportation advantage was assumed to be 10¢/cwt. or $100/1000 cwt.

Table 1. Mill utilization for successive solutions

Solution	1		2		3		4		5		6		7		8	
Mill	Usage 000'cwt	Marginal Cost ¢/cwt	Usage 000'cwt	Marginal Cost ¢/cwt	Usage 000'cwt	Marginal Cost ¢/cwt	Usage 000'cwt	Marginal Cost ¢/cwt	Usage 000'cwt	Marginal Cost ¢/cwt	Usage 000'cwt	Marginal Cost ¢/cwt	Usage 000'cwt	Marginal Cost ¢/cwt	Usage 000'cwt	Marginal Cost ¢/cwt
Memphis, Tenn.	6,995	54.67	7,430	54.48	7,088	54.63	5,502	55.43	2,402	58.35	7,844	54.32	7,918	54.30	6,831	54.75
Jonesboro, Ark.	0		0		0		0		0		5,429	55.48	0		0	
Fair Oaks, Ark.	3,934	56.55	161	72.75	0		0		0		6,268	55.02	11,373	53.24	13,393	52.79
Stuttgart, Ark.	4,592	56.02	8,365	54.13	9,816	53.66	11,681	53.16	14,502	52.57	0		0		0	
Greenville, Miss.	2,935	57.60	2,441	58.29	1,505	60.24	1,212	61.17	1,505	60.24	0		0		0	
New Orleans, La.	0		0		0		0		0		1,092	61.65	0		0	
Crowley, La.	3,863	56.62	1,604	59.97	712	63.67	0		0		10,207	53.55	8,890	53.95	8,042	54.25
Lake Charles, La.	16,158	52.28	21,732	51.52	24,206	51.25	24,918	51.18	24,918	51.18	0		0		0	
Beaumont, Texas	4,638	56.00	1,495	60.26	0		0		0		21,183	51.59	26,411	51.04	26,884	51.00
Houston, Texas	12,035	53.08	13,506	52.77	13,595	52.75	13,868	52.69	13,868	52.69	0		0		0	
Eagle Lake, Texas	314	68.26	0		0		0		0		6,102	55.10	35,181	56.95	2,895	57.65
Louise, Texas	2,719	57.88	1,374	60.63	1,240	61.08	967	62.21	967	62.21	0		0		0	
West Sacramento, Cal.	11,224	53.28	11,597	53.19	11,529	53.20	11,529	53.20	11,529	53.20	0		0		0	
Biggs, Cal.	3,376	57.09	3,015	57.50	3,015	57.50	3,015	57.50	3,015	57.50	0		0		0	
San Francisco, Cal.	0		0		0		0		0		16,033	52.30	16,033	52.30	16,033	52.30
South Dos Palos, Cal.	1,501	60.25	1,490	60.28	1,490	60.28	1,490	60.28	1,490	60.28	0		0		0	
Transport cost	132,284,310		132,439,592		132,593,770		132,732,700		132,744,944		136,699,552		136,781,033		136,837,919	
Mill's cost	43,498,932		42,750,824		42,318,044		42,099,356		42,011,654		42,225,245		41,563,061		41,470,790	
Total cost	175,783,242		175,190,416		174,911,815		174,832,057		174,756,598		178,924,797		178,344,094		178,308,709	
Remarks	Minimum transport cost						First local optimum		Cutting plane used						Second local optimum	

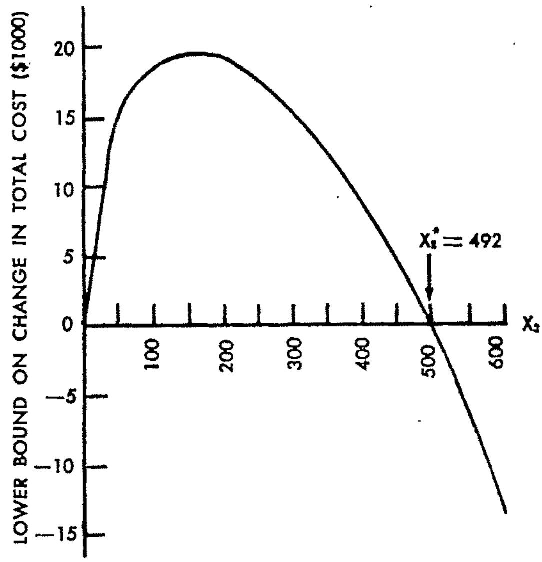

Figure 2. Lower Bound on Change in Total Cost for Reallocation of Rice from Jonesboro.

or

$$\Delta TTC = 932.44x_2 + (967 - x_2)(233.637 + (1357.136/\text{Log}_{10}(967 - x_2))) - 665512.58; \quad 0 \leq x_2 \leq 50.$$

For $50 \leq x_2 \leq 917$ the estimated change in the total cost function is

$$\Delta TTC = x_2(1357.136((1/\text{Log}_{10} x_2) - (1/\text{Log}_{10}(967 - x_2)) - 100) + 1{,}312{,}351/\text{Log}_{10}(967 - x_2) - 439{,}593.37; \quad 50 \leq x_2 \leq 917.$$

For $917 \leq x_2 \leq 967$ the estimated change in the total cost function is

$$\Delta TTC = -100x_2 + 1032.44(967 - x_2) + x_2(233.637 + (1357.136/\text{Log}_{10} x_2)) - 665512.58; \quad 917 \leq x_2 \leq 967.$$

A portion of this segmented estimated change in the total cost function[8] is shown in Figure 2. It is non-negative for all $x_2 \leq 492.78$. Hence, if the throughput is increased at Jonesboro alone, leaving all other inactive mills inactive, total cost will rise unless *at least* 492.78 (1000 cwt.) are reallocated to Jonesboro.

In a similar way the minimum amount that must be reallocated to Fair Oaks, Arkansas, if

[8] Actual change in total cost is on or above this function.

it is the only plant activated, can be calculated, and so on. Combining these estimates, either

1) no other plants have to be considered, or
2) a combined reallocation must satisfy

$$\Sigma_j x_j / x_j^* \geq 1$$

where x_j^* is the minimum amount to be shipped, if the jth plant alone were activated, e.g., $x_2^* = 492.78$, and the summation is over all plants which are inactive at the local optimum being considered.

Each cutting plane reduces the solution space so that eventually, after sufficient cutting planes have been introduced, it can be asserted that "it is not possible to reduce cost by opening other plants."

Setting the appropriate plants to zero, it is then possible to calculate similar bounds which allow either of the following:

1) it is not possible to reduce cost by closing a plant, or
2) a combination of the plants to be closed must not process in excess of

$$\Sigma_j x_j / x_j^* \leq 1.$$

When sets of plants have been established which cannot be closed if a better local optimum is to be found, bounds based on reallocation among these sets of plants are then established.

Computational Experience

The general course of the computations can be seen from Table 1. This table lists the mill utilization levels and transportation and milling costs for each of the approximate linear programming solutions. Mill usage in the first solution is the single solution which would have been reported if it has been assumed that all mills had constant costs. Local optima (solutions 5 and 8) have been indicated.

Only two local optima were obtained, because the difference between known minimum cost, \$174.8M, and the lower bound on this cost, \$172.6M, did not justify an exhaustive search of the solution space, especially in the light of the second local optimum being \$2.5M *above* the initial linear programming solution and \$3.6M above a known local optimum.

Conclusion

This paper has shown the plant location problem with fixed supplies and demands can be regarded as an example of concave programming. It has illustrated an approach to the solution of such problems and reported the results of a fairly large-scale application of the procedure.

The reduction in cost from the transportation approximation to the first local optimum was \$1.02M, or 0.58 percent. This contrasts with similar cost reductions of \$1.34M, or 3.97 percent, for King and Logan's study [3] of cattle plant location. The second local optimum was substantially worse than the initial transportation approximation. The relatively minor gains due to explicit recognition of falling average processing costs stem in part from the fact that the sub-optimal arrangement with high average costs for small volumes by definition affects only small volumes of production. The very low cost reductions found in the present study may, in part, reflect the heuristics used to specify the transportation arrangements to be considered.

Given that an exhaustive search of the solution space is possible, how many local optima should be searched is an economic problem of balancing potential gains against known additional computing expenditures.

References

[1] Frank, Marguerite, and Philip Wolfe, "An Algorithm for Quadratic Programming," *Naval Res. Log. Quart.* 3:95–110, 1956.

[2] Karlin, Samuel, *Mathematical Methods and Theory in Games, Programming and Economics*, Vol. 1, Reading, Mass., Addison-Wesley Publishing Company, Inc., 1959.

[3] King, Gordon A., and Samuel H. Logan, "Optimum Location, Number and Size of Processing Plants with Raw Product and Final Product Shipments," *J. Farm Econ.* 46:94–108, Feb. 1964.

[4] Kuhn, H. W., and W. Tucker, "Nonlinear Programming," in *Proceedings of the Second Berkeley Symposium on Mathematical Statistics and Probability*, ed. Jerzey Neyman, Berkeley, University of California Press, 1950.

[5] McMillan, Claude, *Mathematical Programming*, New York, John Wiley & Sons, Inc., 1970.

[6] Stollsteimer, John F., "A Working Model for Plant Numbers and Locations," *J. Farm Econ.* 45:631–645, Aug. 1963.

[7] Toft, H. I., P. A. Cassidy, and W. O. McCarthy, "Sensitivity Testing and the Plant Location Problem," *Am. J. Agr. Econ.* 52:403–410, Aug. 1970.

[8] Tui, Hoang, "Concave Programming Under Linear Constraints," *Soviet Math.* 5:1437–1440, Nov.–Dec. 1964.

Communications

A DYNAMIC ECONOMIC MODEL OF PASTURE AND RANGE INVESTMENTS: COMMENT

In a recent issue of this journal, Oscar Burt has offered a model for the determination of an "approximately optimal decision rule" for the clearing of brush and scrub timber from pasture and rangeland [1]. The empirical portions draw rather heavily on previous work by Melvin Cotner and since he may have some comments on Burt's model, I shall restrict my attention to what I believe to be a rather serious weakness in the Burt formulation of the range improvement problem.

In general, range vegetation may be classified into two categories: (1) increasers and (2) decreasers. As for the former, these are species which tend to gain in frequency and robustness as a result of grazing. In short, they are species which gain a comparative advantage in a given ecosystem with the demise of the other broad category—the decreasers. This latter group contains those palatable species (nutritious or not) which are preferred by the grazing animals. In gross terms, certain grass species and broad-leaved herbacious species comprise the class of decreasers and certain species of brush (sage and rabbit) and Pinyon and Juniper comprise the class of increasers.

It is the very essence of grazing management to find the proper combination of plant predators (sheep, cattle, wildlife) to hold the vegetative system in some suspended state of serial progression towards an ecological climax. That is, grazing itself is a management tool in the ecosystem. One of the most significant ways in which "investment" occurs in such a world is through the judicious balance of such factors as grazing intensity, grazing frequency, season of grazing, type of animal grazed, and wildfire. Because the latter factor has virtually been eliminated through the "Smokey the Bear" campaign, we are left with but two management devices: (1) grazing and (2) artificial range rehabilitation.

My challenge to Burt lies in his failure to include grazing in his model of the optimal timing of the clearing of brush and timber; the invasion of which is primarily a function of those factors excluded from Burt's model. Indeed, with stocking rate assumed fixed, one is seemingly left with an "optimal" investment model which ignores the rate of use of the "equipment" and "maintenance and repair." While Burt should be commended for his efforts to impart some rigor into an area heretofore more dependent upon intuition than analytics, I am concerned that those who employ his model on a range improvement problem would be less aware of the significant role of grazing than he is, and hence would tend to generate some rather curious policy recommendations.

Daniel W. Bromley
University of Wisconsin

Reference

[1] Burt, Oscar R., "A Dynamic Economic Model of Pasture and Range Investments," *Am. J. Agr. Econ.* 53:197–205, May 1971.

A DYNAMIC ECONOMIC MODEL OF PASTURE AND RANGE INVESTMENTS: REPLY

Daniel Bromley has criticized [2] my superficial treatment of grazing as a decision variable, but much of the apparent deficiency in the model emanates from my incomplete exposition of how the model might be used. There is little empirical evidence to support or refute the importance of grazing on the rate of encroachment of brush and scrub timber. Certainly, there must exist some interaction, but a critical question is its relative importance; i.e., can we ignore it for practical purposes on many types of pasture and range?

Let us give Bromley the benefit of a doubt and assume an important interaction exists. Assuming empirical measures are available, we then specify several grazing policies as candidates from which to select. Experience and judgment would need to be relied upon in putting together this set of alternative policies. A grazing policy constitutes a rule to be followed in applying various grazing practices to the pasture or range throughout a renewal cycle, but length of the renewal cycle is left as a variable.

With a grazing policy specified, my model can be

applied to derive an optimal renewal cycle and its associated present value of net returns. The grazing policy yielding highest present value of net returns in conjunction with its optimal renewal cycle is the "best" among those evaluated. The primary limitation with this approach is knowing *a priori* the set of grazing policies that are worthy of consideration.

A more complete model which would determine the optimum grazing policy simultaneously with the renewal cycle was briefly outlined in [3, pp. 202–203]. As pointed out there, a straightforward generalization of the model would lead to a problem in the calculus of variations with discontinuities in one of the state variables. It appears more feasible to go to a dynamic programming model with the stage defined on the basis of a fixed time period instead of the renewal cycle.

Such a model is formulated below with one grazing variable called stocking rate. With the stage of the process defined by a fixed time period, a year, for example, the Markovian dependence structure would require two state variables to describe the state with respect to encroaching brush and timber if we use cycle lengths as state variables. A state variable for length of the previous cycle and years since the last renewal would constitute these two variables; then a third state variable would be required to accommodate the grazing variable, *viz.*, stocking rate.

Instead of going this route, let us begin with the model associated with equation 11 [3, p. 202] since one less state variable is required. As there, y is a state variable defined as an index of range productivity at a given stage of the process. To be more concrete, let y be the proportion of the surface covered by productive range species. (In general, y would be a vector of state variables.)

The second state variable is denoted by x and is current stocking rate. The two decision variables are (1) change in stocking rate and (2) a dichotomous variable designating renewal or no renewal. These two variables are denoted by u and v, respectively.

The transformation function for the range index is $\phi(u, v, x, y)$ and that for stocking rate is $x+u$. Thus, letting n denote a stage within the process, where the nth stage implies n years remaining in the planning horizon,

$$y_{n-1} = \phi(u_n, v_n, x_n, y_n) \tag{1}$$

$$x_{n-1} = x_n + u_n. \tag{2}$$

The net revenue function per stage is denoted $G(u, v, x, y)$. Applying Bellman's principle of optimality [1], the recurrence equation of dynamic programming is

$$f_n(x, y) = \max_{u,\, v}\left[G(u, v, x, y) + f_{n-1}(x + u, \phi(u, v, x, y))/(1 + i)\right] \tag{3}$$

and as $n \to \infty$, $f_n \to f_{n-1}$ to yield the functional equation associated with an infinite planning horizon. The function $f_n(x, y)$ is discounted net returns from an n-stage process under an optimal policy if the process starts initially with the state variables at x and y. If transformation of the state variable y is a stochastic phenomenon, equation (3) is modified as explained in [3, p. 202], in regard to equation 11 there, to accommodate an expected value criterion function.

Equation (3) can be solved numerically quite readily on an electronic computer by established methods [1]. Space does not permit elaboration on the structure of the functions $G(u, v, x, y)$ and $\phi(u, v, x, y)$, but any serious researcher in range management should quickly see the interrelationships involved. The big challenge to range scientists is empirical measurement of these functions.

OSCAR R. BURT
Montana State University

References

[1] BELLMAN, RICHARD E., AND STUART E. DREYFUS, *Applied Dynamic Programming*, Princeton, Princeton University Press, 1962.

[2] BROMLEY, DANIEL W., "A Dynamic Economic Model of Pasture and Range Investments: Comment," *Am. J. Agr. Econ.*, this issue.

[3] BURT, OSCAR R., "A Dynamic Economic Model of Pasture and Range Investments," *Am. J. Agr. Econ.* 53:197–205, May 1971.

MORE SOPHISTICATED TOOLS FOR LESS IMPORTANT PROBLEMS: THE HISTORY OF RANGE IMPROVEMENT RESEARCH: A COMMENT

A classical way in which comedy is developed is to set up a given situation, then follow the implications of this situation to apparently logical, but totally absurd, conclusions. Burt, in his recent article, "A Dynamic Economic Model of Pasture and Range Investments" [1, pp. 197–205], provides a marvelous tragicomic capstone to a line of research that has been logically developed by agricultural economists over the past 18-plus years.

Having been a part of this continuing situation comedy, I'd like to share my enjoyment with fellow *Journal* readers.

In 1953, Regional Research Project W-16, the "Economics of Rangeland Improvement," was activated. The first objective of the project was

> To facilitate orderly development and conservation of the present or potential rangelands of the western region by economic evaluation of the costs and returns from range revegetation or rehabilitation and closely associated practices.

The project also listed two other objectives which were essentially redundant. The essence of the project was that economics of range revegetation or rehabilitation investments were to be studied.

Six years after the project was initiated in 1959, it was narrowed in scope. The two revised objectives were, "to study costs and methods of range improvement practices . . ." and "to study effects of . . . improvement practices . . . on net returns of private ranch operations."

Finally, in October 1964, the termination report was submitted to whomever termination reports are submitted [8].

Although the termination report naturally claimed "the objectives of the original project . . . were substantially completed," it was quite obvious why the project had been revised and narrowed in scope. The eight publications listed for the original project better satisfied the much narrower objectives of studying costs of practices and net returns on ranches; therefore, the objectives were revised to fit the forthcoming results.

Twenty-six publications were listed for the revised project. Some of the titles even seem relevant to the revised objectives. Gray and Saadi [7] in the final report of the WAERC Committee on the Economics of Range Use and Development, a bibliography on range and ranch economics, list 85 publications in the area of range improvements, most of which were developed either within W-16 or as spin-offs.

However successful W-16 was in satisfying the specified objectives, a review of its work showed one thing: a lot of people put in a lot of time trying to understand the economics of range improvement investment. They were relatively unsuccessful in their efforts not because of a lack of economic sophistication, but because the response data relative to improvement practices were almost totally lacking. That the problem itself was considered important is not surprising. The 1950's were the heyday of agricultural economics research in commercial agriculture.

A review of the history of this work also showed that the more evident it became to the individual researcher that data were lacking in quantity and quality adequate to obtain useful research results, the more elegant the models presented for possible use (at some future time) became.

One man tried to do something about this lack of data. During the late 1950's, working outside of W-16, M. L. Cotner of the Economic Research Service was stationed at the University of Arizona where he worked cooperatively with range improvement specialists to develop some response data to make economic analysis of range improvement investments actually possible. One technical report based on this work was finally published by the Arizona Agricultural Experiment Station in cooperation with the ERS [2, 4], but only after a long struggle with range improvement specialists in the review process. From the specialists' point of view, too many assumptions about the experimental data were necessary to make the data amenable to economic analysis. That they could provide no better data did not sway them from their oath of small-plot experimental purity. Thus, the final report was a "watered down" version of the original manuscripts. Cotner, bowing to the inevitable flow of events, salvaged what data he could and published his 1963 article, "Optimum Timing of Long-Term Resource Improvements" [3], a model illustrated with almost hypothetical data (at least from the specialists' point of view).

In 1966, Dickerman and I, both relatively new in the range economics field, added to this chain of absurd events. Noting that previous efforts at economic analysis of range improvement practices were not satisfactory, we decided to attempt our own analysis. Our approach was twofold. First, a general theoretical model was devised; second, a search of literature and range specialists was made to try to obtain enough data to make the model operational [5, 6].

Aside from being an interesting intellectual exercise (and without claiming that our model was superior to several others that had been proposed), our efforts also were wasted. Data were not available to implement our model. Data were not adequate for any of the other less general models; they still are not, and it is unlikely that they ever will be.

This short history brings me to Burt's capstone, "A Dynamic Economic Model of Pasture and Range Investments" [1], perhaps better titled, "Another Article in a Continuing Series on the Possible but Impractical Uses of Dynamic Programming." Burt recognizes that "the traditional economic replacement problem [can be] extended to accommodate a situation where quasi-rents of future replacement are influenced by replacement age of the currently held asset" [1, p. 197]. Conceptually, range improvement investments provide a possible example. Dynamic programming offers a method for handling such a problem. Therefore, an article is developed where dynamic programming can be used to illustrate the problem and give a simple example with *almost* hypothetical data (*some* of Cotner's data from his article are used in the example).

By the time this historical stage in the analysis of range improvement has been reached, work in range improvement, other than for Cotner's article [3] (from which the almost hypothetical data were obtained), need not even be mentioned. The overwhelming lack of response data has produced an evolutionary change to complete mathematical purity. Burt's article really is not about range investments at all. For example, "Any variables, such as stocking rate, which might interact with the rate of encroachment of brush are assumed to be fixed and are not part of the optimization process." Also, "The methods of control used from one renewal to

another are assumed equivalent in physical performance" [1, p. 198]. Burt's article is about an application of a tool to a generalized problem that fits the specifications of the tool. Elegance is the medium, and the "medium has become the message."

The comic chain has been completed and such fun it has been. Its tragicomic overtones, of devoting so many resources to the job, can perhaps be overlooked in view of the amusement generated. However, I suspect that the members of W-16 had some inkling of the relative usefulness of continuing range investment work when the project was terminated in 1964. Now, in 1971, the range improvement problem is not of real importance to much of society.

WILLIAM E. MARTIN
University of Arizona

References

[1] BURT, OSCAR R., "A Dynamic Economic Model of Pasture and Range Investments," *Am. J. Agr. Econ.* 53:197–205, May 1971.

[2] COTNER, MELVIN L., *Controlling Pinyon-Juniper on Southwestern Rangelands*, Ariz. Agr. Exp. Sta. Rep. 210, March 1963.

[3] ———, "Optimum Timing of Long-Term Resource Improvements," *J. Farm Econ.* 45:732–748, Nov. 1963.

[4] ———, *Economic Considerations in Controlling Pinyon-Juniper on Northern Arizona Cattle Ranches*, Ariz. Agr. Exp. Sta., unpublished.

[5] DICKERMAN, ALAN R., "An Economic Model for the Analysis of Southwestern Range Forage Improvement," unpublished M.S. thesis, University of Arizona, 1966.

[6] ———, AND WILLIAM E. MARTIN, "An Economic Model for the Analysis of Range Forage Improvement," *Economic Research in the Use and Development of Range Resources*, Report 9, Proceedings of the Committee on Economics of Range Use and Development, Western Agricultural Research Council, 1967.

[7] GRAY, JAMES R., AND MOHAMED A. A. EL SAADI, "Range and Ranch Economics Bibliography," *Economic Research in the Use and Development of Range Resources*, Report 11, Committee on Economics of Range Use and Development, Western Agricultural Research Council, 1969.

[8] Regional Project W-16 Technical Committee, termination report, (1) original project, "Economics of Rangeland Improvement"; (2) revised project, "Economics of Range Resource Use," Oct. 2, 1964 (processed).

MORE SOPHISTICATED TOOLS FOR LESS IMPORTANT PROBLEMS: THE HISTORY OF RANGE IMPROVEMENT RESEARCH: REPLY

The most disturbing thing about William Martin's observations and expressed opinions is that they reflect a general philosophy and mood toward research which seems to be evolving. Research that does not culminate in a solution or partial solution to an immediately pressing problem of society is considered a waste of resources. Those with this view are the people who would program research activities along very narrow lines and in their infinite and divine wisdom decide the avenues to be explored. The very nature of research is such that forthcoming results can only be vaguely predicted, and often the usefulness of the results is subject to even greater uncertainties.

Anybody who condemns a piece of research as merely a contribution to frivolous comedy should have a better basis than the absence of sufficient data to estimate the required empirical measures implied by the research. It is easy to get into a circular argument when trying to explain why such data have not been obtained and the statistical estimation completed. One answer is that without an adequate economic model, the required relationships cannot be specified. Consequently, the type of data needed is still unknown and certainly an efficient experimental procedure cannot be developed. If we follow Martin's philosophy, the requisite economic model will never be developed because the data base and empirical measures are unavailable, which completes the circle.

Thus, Martin is willing to "write off" range research as futile because necessary relationships will probably never be available. Not only that, but anybody engaged in research that is concerned with the economics of the problem is supposedly wasting his time. If scientific progress were dependent upon this kind of zeal, we would still be farming with sticks.

Let me now answer some of the innuendos about my motives for writing the article [1] and the limitations of the model developed therein. In regard to my motives, pasture and range investments in clearing brush and scrub timber appeared to be an important and challenging problem in economic dynamics. It was apparent that an adequate conceptual framework had not been developed, and that progress in measurement of the biological phenomena involved was very likely dependent upon a better understanding of the relationships required for an economic model. The fabrication required in applying Cotner's data to a complete economic model should substantiate this latter point.

Use of dynamic programming in the analysis was incidental. Professor Martin should be aware that dynamic programming is a powerful mathematical method for analyzing dynamic optimization problems. Modern control theory is the other method most likely to have been used, but I found dynamic programming more appropriate. If he can show me advantages in using another method, I would be most happy to listen.

As far as "mathematical purity" is concerned, it is

a ludicrous term. Certainly there is virtue in simplicity in any theory or model, *if the essence of the phenomena under study can be captured in that simplicity*. Or stated crudely, do not make economic models any more complex than necessary to be reasonably accurate and useful. The model dwelt upon in [1] was considered by the author to be a reasonable compromise, but some discussion was given to more complicated models if circumstances required them [1, pp. 202–203]. More elaboration on models that encompass grazing variables as dynamic decision components is given in my reply to Bromley's criticisms [2].

It appears to me that Martin has confused elegance with rigor and logical correctness in economic analysis. We too often find poor and inadequate data used as an excuse for slipshod economic analysis. It is also common to see static economic theories cobbled to deal with dynamic problems when the only correct procedure is to approach the problem for what it is—a truly dynamic phenomenon. It would seem that the least we can do as economists is to develop rigorous economic models of the problems that we study.

Oscar R. Burt
Montana State University

References

[1] Burt, Oscar R., "A Dynamic Economic Model of Pasture and Range Investments," *Am. J. Agr. Econ.* 53:197–205, May 1971.

[2] ———, "A Dynamic Economic Model of Pasture and Range Investments: Reply," *Am. J. Agr. Econ.*, this issue.

CHANGED DISTRIBUTION OF INCOME VS. REDISTRIBUTION IN PUBLIC PROJECT EVALUATION: COMMENT

Economists are giving increasing attention to the distributive effects of public investment projects. However, empirical work will be handicapped by conceptual confusions in the current literature. A key distinction is between changes in the distribution of income over time by income classes and redistribution of income from one class to another.[1] The first situation describes the fact that a given income class would receive, for example, 10 percent of the national (regional, or whatever) income without the project over a given time period, and as a result of some public project it will now receive 12 percent. This is a change in the distribution of income, but it says nothing of the source. It could be a result of the discovery of some very productive investments whose benefits can be captured by a particular group which raises its income relative to other groups, or it could be the result of a transfer of income from other groups to the particular group with no increase in national income.

For the above reason, I wish to distinguish between a change in income distribution and redistribution of income. Kalter and Stevens [2] offer the following definition which I embrace: "Income distribution is changed by federal resource investments whenever the distribution of project net benefits is nonproportional to the income distribution projected to occur without the project in question." This is consistent with the above numerical example and is adequate as far as it goes. But the public will want other information, such as whose pocket this gain came from, if any. Redistribution in a common sense meaning implies that money which was once legitimately in one person's pocket is now transferred to another. I suggest the term "redistribution" be limited to this and not confused with the total change in distribution of income.

If I invent a better manufacturing process and thereby enhance my income relative to others, there is a change in income distribution but not a redistribution if I pay all of the cost of the development and capture no income that otherwise would have gone to others. Under this situation, there is a pure productivity gain which results in a changed distribution, but no redistribution.

The empirical measure of redistribution is made difficult by the establishment of what money is legitimately in one person's pocket. This is especially difficult in public projects where there are multiple beneficiaries and joint benefits. If there is a single beneficiary group that pays all of the cost through special tax assessment or user fees, there is no redistribution. There may be a changed income distribution if the project has a positive net return. If some other group pays part of the cost there is also redistribution to that extent.

What if there are two beneficiary groups and the costs of the benefits to them are inseparable? Some cost sharing is required and public policy must define the legitimate base for that cost sharing. Suppose the accepted sharing of costs in a joint enterprise is in proportion to benefits. This means if one group gets 50 percent of the benefits it should pay half of the costs. If the group pays only 25 percent of the costs, part of the changed income distribution is due to redistribution. Redistribution for a group can be defined in terms of the costs that "should" have been paid but are picked up by some other group.

To be more precise, let project benefits which are

[1] This distinction was clarified in the context of a continuing discussion with Daniel Bromley [1].

the difference between the with and without situation be called gross benefits. Therefore, GBi represents the present value of gross benefits to group i as a result of the project. Let Ri^* represent the present value of actual costs paid by the group (whether in taxes or other reimbursements) and Ri' represent the costs that would be paid if costs were shared in the usual way (assumed to be proportionate to benefits in this case). Thus, if net benefit to group i be represented by NBi^* then,

(1) $NBi^* = GBi - Ri^*$

We can then inquire further into the source of the net benefit.

(2) Redistribution $= Ri' - Ri^*$

(3) Productivity gain $= GBi - Ri'$

It is now possible to show the public that the components of net benefit to a given group may include redistribution plus a selective productivity gain.

(4) $NBi^* = (Ri' - Ri^*) + (GBi - Ri')$

Note that redistribution may run in favor of the given group or against it. This is also true of productivity gain which can be negative.

Some of the gain for the given group can result from someone else picking up its share of costs and part from the productivity of the project which falls on the given group. However, the net benefit alone says nothing about whether group i has changed its position relative to other groups. If there is a redistribution component we know there has been some change in income distribution, but this is not alone a function of redistribution. To describe the change in income distribution we need to know the without project income distribution.

If we know the percentage distribution of net income without the project to the given group, we can calculate the amount of net benefits that the group must receive from the project to hold its own. Let this be represented by NBi'. The difference between what it actually receives, NBi^*, and what it would receive if it got the same proportion of project net benefit as it had of total national income (or other area), NBi', indicates the size and direction of the actual change in net income due to the project.

(5) Change in income distribution $= NBi^* - NBi'$

If the sign of the above equation is positive, the group has improved its income position relative to other groups, other things being equal.

It should be noted that it is quite possible for there to be redistribution without the target group being made better off. One group can give income to another, but lose part of it in inefficient investments. This will change relative incomes, however. One solution to income inequality is for the charitable to throw their money away, but at least our documentation of project effects ought to make this clear. This is why I suggest it is important for economists to distinguish redistribution from a change in distribution and to keep track of the amount given up by the grantor.[2]

Kalter and Stevens [2, p. 207] have been critical of an earlier formulation [4] of the above because it stopped at the delineation of net benefits and its components and did not discuss a reference point for distribution change. The criticism is accepted and hopefully corrected here. I can only suggest that they in turn include in their documentation of distributive effects a differentiation of selective productivity gain and redistribution as components of net group benefit when its proportion of project benefits is compared to the group's proportion of area income to calculate change in income distribution.[3] All are needed to fully inform the public.

A. ALLAN SCHMID
Michigan State University

[2] Lest the reader unfamiliar with the literature think that I have created a straw man to knock down, consider the following: "*redistribution benefits* are the consumption gains of particular groups or regions. . . . The gains to a particular group of project users are the *difference* between their willingness to pay and the actual charges levied upon them" [3, p. 45]. For conceptual clarity I prefer to call this net benefit to a particular group, only a part of which may be redistribution.

[3] Nowhere in Kalter and Stevens [2] is the amount of redistribution highlighted, although in their numerical example several groups receive net benefits which improve their relative income position. Yet, the project is inefficient. The fact that part of the transfer is lost is ignored.

References

[1] BROMLEY, DANIEL, A. ALLAN SCHMID, AND WILLIAM LORD, *Public Water Resource Project Planning and Evaluation: Impacts, Incidence and Institutions*, to be published in Madison, Center for Resource Policy Studies and Programs, University of Wisconsin.

[2] KALTER, ROBERT J., AND THOMAS H. STEVENS, "Resource Investments, Impact Distribution, and Evaluation Concepts," *Am. J. Agr. Econ.* 53:206–215, May 1971.

[3] MARGLIN, STEPHEN A., *Public Investment Criteria*, Cambridge, the M.I.T. Press, 1968.

[4] SCHMID, A. ALLAN, "Effective Public Policy and the Government Budget: A Uniform Treatment of Public Expenditures and Public Rules," in *The Analysis and Evaluation of Public Expenditures: The PPB System*, Vol. 1, U. S. Congress Joint Economic Committee, Subcommittee on Economy in Government, 1969, pp. 579–591.

CHANGED DISTRIBUTION OF INCOME VS. REDISTRIBUTION IN PUBLIC PROJECT EVALUATION: A REPLY

As a general proposition, full public disclosure of information about the formulation and impacts of governmental resource investments cannot be faulted. This is one of the primary arguments favoring the use of multiple objective planning techniques [2, 6] and an important thrust of our recent article [3]. However, information useful to public decision making must be relevant to the issues of social concern. If we have properly interpreted Schmid's comment [5], his position does little to clarify this concern and appears to be based on several misinterpretations of our recent article. In addition, his comments create several conceptual confusions by being ambiguous with respect to the definition of terms and concepts held out for acceptance. Our reply is directed toward these issues.

Schmid begins by indicating that the terms "changed distribution" and "redistribution" of income should be used to connote the results of two different (but not mutually exclusive) processes. We agree completely.[1] In fact, that is why the term "redistribution" does not appear in our original article, except in criticism of an earlier formulation by Schmid [4] (which he has accepted). Our formulation is concerned only with the distribution of project impacts which could bring about a *change* in income distribution.[2]

Schmid continues, however, that empirical estimates of a change in the distribution of income will not indicate the source of that change. This leads him to two distinct criticisms of our formulation, both of which involve definition of the word "source." For purposes of clarity we will deal with them separately, taking the least important first.

One interpretation (implied in his footnote 3) is that models which permit estimation of the distribution of project income impacts cannot, for some reason, provide a complete accounting of such effects for a set of impact groups. More specifically, Schmid implies that losses of certain groups are not made clear by our empirical example [3, pp. 210–213]. The key here is the classification of impact groups. Our model assumes that the analysis of equity impacts proceeds by considering only one *set* of impact groups at a time *and* that the total population of the relevant geographic area will be encompassed by that set. Thus, personal income classes, racial classes, age classes, regions, etc., are all sets of impact groups which must be considered separately for evaluation in a multiple objective social welfare function. Obviously, any set with a nonspatial orientation can pertain to the nation or be confined to the population of a defined region. Those sets of impact groups which are relevant to the decision-making process should all be considered in project evaluation.

Taken in this light, Schmid's conclusion is incorrect. The display of income changes was not for "target groups" of our set but for *all* elements of that set. This permitted us to ascertain the aggregate losses, as well as gains, of all individual groups within the set under any conditions of economic efficiency. Schmid obviously failed to recognize that our empirical example pertained to personal income classes for the population of a small region surrounding the project rather than to the population of the nation. From a regional viewpoint the project was economically efficient with a benefit-cost ratio of 5.2 even though inefficient from the national perspective. The transfer ignored by the example was the one between regions, not that between personal income classes within the defined region. There all groups gained because of the nature of the benefit and cost incidence and the economic efficiency of the project from their standpoint. All this was pointed out in the original article.

We do agree that information on the regional distribution effects, as well as the personal income distribution effects for the nation, of public projects would be relevant to a decision-making function. Other impact classifications may also be relevant. These impacts should not and would not be ignored under a full multiple objective social accounting framework.[3] However, our article, and especially the empirical example, made no pretext of being that wide ranging.

Schmid's main suggestion is that distributional effects upon each segment of a set of impact groups should be separated as to their origin (i.e., using his terminology, by the productivity gain and redistribution components). The rationale for such a separation is less than clear from the policy perspective. Does it add relevant information to the display? We doubt it. An impact group (gainer or loser) is usually not concerned with the proportion of its impact that stems from various causes. To a particular group, a

[1] We do, however, reserve the right to redefine his definition of the latter term at a later point.

[2] It should be noted that our model does not result in a display of income distributions with and without a public project; it only displays the distribution of net project benefits and allows them to be compared with some projection of "without" project income distribution. Since we are dealing with publicly provided benefits of an "income in kind" nature, they will not correspond to values included in the standard national income accounting framework. Ascertaining exact changes in income distribution due to public projects will require additional conceptual work on the proper income base.

[3] For example, a reevaluation of the personal income distribution impacts from a national accounting stance for our example results in the following: the project becomes inefficient and, thus, shows an overall loss (cost) to the nation. However, both the lower and middle income classes gain, while the upper class loses proportionately more than their relative income position due *both* to the incidence of the productivity loss and transfers among classes.

such experience, one simply takes these things on faith, trusting in one's "betters" to do the right thing. Perhaps this trust has been misplaced.

Castle's carefully considered comments, together with my personal observations as a judge, suggest that there has never been a very satisfactory basis for reaching a real consensus as to those dissertations which deserve recognition against those that do not. Another difficulty is that some so-called "judges" have not been well qualified. Some of these, together with some others who *may* have been qualified, have not taken the judging very seriously. This is a most unfortunate combination of circumstances, because all concerned, and especially the nominees for awards who have not made it, have felt constrained to keep quiet as a matter of personal honor. (These comments are undoubtedly in gross violation of the accepted code in such matters.)

We have now reached an era in which "there are growing indications that some of our brightest students and some of our younger scholars are no longer willing to accept the criteria for excellence" [3, p. 3] which most of us have lived by over the years. Since we must now defend these very criteria which we *have* tried to support, how can we possibly defend on overblown awards program for which appropriate selection criteria have not been established?

The conclusion seems inescapable that, as far as our association is concerned, the awards tail has begun slowly but surely to wag the AAEA dog. We have gone overboard on these awards, perhaps no more so than American society at large, but certainly more than any other professional society or association of any standing. It is time to reverse this trend and to begin to de-emphasize awards.

We recently had a membership referendum on the question of changing the name of our association to Agricultural and Applied Economics Association.[4] Serious consideration should also be given to the possibility of giving our whole membership a chance to express its views on the awards program after such period of time as may be necessary to publicize both the facts in the matter and the various possible conflicting views.

ERNEST W. GROVE
Agricultural Stabilization and Conservation Service
USDA

[4] A more descriptive choice would have been "Agricultural and Awards Economics Association (AAEA)"! We do more awarding than applying, and the awards are not usually for relevant applications.

References

[1] CASTLE, EMERY N., "Report of the Awards Committee," *Am. J. Agr. Econ.* 52:858–860, Dec. 1970.
[2] GROVE, ERNEST W., "Econometricians and the Data Gap: Comment," *Am. J. Agr. Econ.* 51:184–188, Feb. 1969.
[3] PALMER, ROBERT B., "The New Unreason: Its Implications for Phi Beta Kappa," *The Key Reporter* 36(3): 3–4, 7, Spring 1971.

HAS THE AAEA BECOME "AWARDS HAPPY"?: A REPLY

I am pleased Ernest W. Grove has seen fit to comment on my report given to the Executive Board in August 1970. Dialogue on the awards program is needed and Grove certainly opens up many areas for discussion.

Most of Grove's discussion can stand or fall on its own merits. In several places, however, he refers to me and in some instances makes inferences regarding my position or meaning. Perhaps minor clarification of some of these points would contribute to more precise communication.

I fail to detect the error in my reasoning relative to the continuation of the awards program. Certainly nothing Grove says exposes a fallacy. (1) My assumption is that the association is a reasonably democratic organization. (2) My judgment is that the majority of the membership favors the program. (3) My conclusion is that the program should be continued. My assumption may be unwarranted and/or my judgment may be in error, but the logic books I consult fail to identify an error in reasoning. With respect to the correctness of the reasoning, I consider my own value judgments as well as the fact that I am a scientist, even a social scientist, to be irrelevant. It must have been "the old fashioned prose" rather than the "reasoning" that was at fault.

Grove himself indulges in some highly confused writing. (I will be charitable and blame the prose rather than the reasoning.) First, he distinguishes between the AAEA power structure and the rank and file membership making it clear the two do not think alike on this issue. Second, he says I reflect the views of the "power structure" rather than the "rank and file." He concludes that I have opted for continuation of the program because I have been thoroughly briefed by the power structure. The only thing wrong here is that it leaves no room for the fact, which Grove noted several paragraphs earlier, that my judg-

ment is that the awards program is more of a liability than an asset to the profession. Apparently the "briefings," none of which I can recall, were only partly successful!

Again, I express my appreciation to Grove for stimulating discussion. May all succeeding discussion be "rigorously reasoned."

EMERY N. CASTLE
Oregon State University

PH.D DISSERTATION AWARDS: DOES THE BEST ALWAYS WIN?—COMMENT*

Annually, the AAEA singles out three doctoral theses for special recognition. Although the winning dissertations are selected only after rigid reviewing by 12 judges, statistical comparison of scores shows there is *very little* difference in the scores of the winning contestants, or for that matter, in the scores of any of the contestants in the final round of judging!

These slight differences in scores can be seen in Table 1. Note that even though Contestant E received more total points than Contestant A, Contestant A received more first place votes and had a higher rank score.

Table 1. Final round rankings

Contestant	Total scored	Score excluding highest & lowest scores	Rank scores	Number of first places	Final decision
B	1001	833	41	2	1
G	998	839	46	1	2
A	987	830	38	5	3
E	988	833	48	0	4
D	984	818	43	2	5
F	968	800	58	1	6
C	959	801	58	1	7

Source: Data used in this communication were provided by the judges in 1971 and were summarized by Willard F. Williams, chairman of the Ph.D. Dissertation Awards Committee.

Although the results, to which I am a party, are defensible, there must be *some* way to improve the judging process.

It is not surprising the final results show that winning dissertations may not be the "best" based on the criteria of judges of a given specialty area within agricultural economics. Winning theses may not receive the most first place votes (Table 1). In fact, they are usually *general* dissertations which are not too objectionable to anyone. Consequently, they receive a significant number of second, third, and possibly fourth place votes.

Table 2. Analysis of variance

	Degrees of freedom	Sum of squares	Mean square	F
Among	6	112	20	.377
Within	77	4108	53	
Total	83	4225		

In the initial rounds of judging, it appears relatively easy for a committee to select distinguished Ph.D. dissertations. But it is in the final round that such close scoring occurs. Part of the problem is that the individual judges are experts in their specialties but may have only a peripheral acquaintance with the material treated in the submitted dissertations.

Since dissertations are ranked on a 0–100 point scale, it is possible to test the hypothesis that the mean scores given the theses by the judges are equal. The contestants can be considered treatments and the judges' raw scores replications in a one-way classification experiment (Table 2). The hypothesis cannot be rejected at the 50 percent significance level! Therefore, statistically, it is impossible to select a winner from the seven contestants.

Emery Castle, past chairman of the overall Awards Committee, has said in the long run excellent Ph.D. dissertations are probably recognized [1]. This statistical analysis tends to substantiate the alternative hypotheses that either judging is a relatively subjective process in rating a heterogeneous product, or the profession produces many excellent Ph.D. dissertations of nearly equal quality.

GAIL L. CRAMER
Montana State University

* I appreciate the helpful suggestions of R. Clyde Greer.

Reference

[1] CASTLE, EMERY N., "Report of the Awards Committee," *Am. J. Agr. Econ.* 52:858–859, Dec. 1970.

OPTIMAL SIZES OF FARMS UNDER VARYING TENURE FORMS, INCLUDING RENTING, OWNERSHIP, STATE, AND COLLECTIVE STRUCTURES: COMMENT

Professor Earl O. Heady [1] asserts that the optimum farm size as viewed by the share tenant will generally result in an output level different from that at which profit is maximized for the owner-operator. Only when the tenant shares in cost in exact proportion to his share in revenue will the profit-maximizing level of output for the tenant conform with the profit-maximizing level of output for the owner-operator.

Heady's formulation of the problem is

$$\pi_t = rP_yY - s\sum_{i=1}^{n} P_iX_i$$

where P_yY is the value of production, P_iX_i is the expenditure on the resource i, π_t is the tenant's profit, and r and s are the proportions of revenue and expenditure shared by the tenant. His profits are maximized when

$$\frac{\partial \pi_t}{\partial X_i} = rP_y\frac{\partial Y}{\partial X_i} - sP_i = 0$$

or

$$MRP(X_i) = \frac{s}{r}P_i.$$

Only when $r=s$ will the tenant utilize resources to the point where marginal revenue product is equal to product price. It can also be seen that whether or not $r=s$, the tenant will produce a given level of output with the cost-minimizing combination of inputs since

$$MRS(X_iX_j) = \frac{P_i}{P_j} \qquad \begin{matrix} i \neq j \\ i = 1, \cdots, n \\ j = 1, \cdots, m. \end{matrix}$$

In an attempt to obtain a more general formulation of Heady's model, the above condition of cost minimization was found to be inadequate. In fact, the share tenant will likely choose to produce a given level of output by employing other than the cost-minimizing combination of inputs. This more general formulation of Heady's model and the first order conditions for profit maximization are

$$\pi_t = rP_yY - \sum_{i=1}^{n} s_iP_iX_i$$

$$\frac{\partial \pi_t}{\partial X_i} = rP_y\frac{\partial Y}{\partial X_i} - s_iP_i = 0$$

or

$$MRP(X_i) = \frac{s_i}{r} \qquad i = 1, \cdots, n.$$

This approach allows the tenant to provide varying proportions of the different resources or none of some resources. The profit-maximizing condition suggests that the tenant's optimum level of output will equal that of the owner-operator only when $s_i=r$ for all i. Furthermore, the share tenant is likely to produce any given level of output with something other than the cost-minimizing combinations of inputs since

$$MRS(X_iX_j) = \frac{s_i}{s_j}\frac{P_i}{P_j}.$$

This result contradicts that implied by Heady's model except in the case $s_i=s_j$ for all $i, j: i\neq j$. This latter equation implies the share tenant will have an incentive to either over- or undercapitalize should $s_i \neq s_j$.

Professor Heady derives the optimum farm size from the point of view of an owner leasing to a share tenant. Under Heady's formulation of the problem, the optimum size for the share owner will differ from the optimum size for the share tenant except when $s=r$. In this circumstance the optimum farm size of the owner-operator, share tenant, and share owner will coincide. Since in many cases $s\neq r$ (or in the more general formulation, $s_i \neq r$ for all i), the share tenant and the owner may not agree on the optimum farm size or the optimum employment of resources. So although Heady's formulation of the problem of optimum farm size produces some interesting results, it leaves a basic question unanswered; that is, how will farm size actually be determined in the case of a share tenant?

An alternative formulation of this problem produces a determinant farm size for the case of a share tenant and is given by

$$MAX: \pi_t = rP_yY - \sum_{i=1}^{n} s_iP_iX_i$$

$$\text{Subject to: } \pi_0 = (1-r)P_yY - \sum_{i=1}^{n}(1-S_i)P_iX_i$$

where π_0 is the owner's profit, $(1-s_i)$ is the proportion of the ith input supplied by the owner, and $(1-r)$ is his proportionate share of revenue. This formulation suggests the share tenant attempts to maximize his remuneration, subject to providing the owner with an acceptable level of profit or return on his investment. The successful tenant has a good feel for the minimum acceptable level of profit which the owner expects to receive on his investment. Generally, this return will be related to the risk and opportunity costs associated with the resources supplied by the owner. Additional restrictions might include limitations upon any or all of the resources supplied by the owner and limitations on the tenant's supply of labor or capital. The important point is that farm size is ultimately determined by the tenant who has rather broad discretionary powers subject to one or more constraints placed upon him by the owner. The share tenant's situation is, in fact, some-

what analogous to a corporate manager who attempts to maximize a quantity such as sales, output, or profits contingent on providing stockholders with an acceptable return on invested capital.

Writing the alternative formulation in Lagrangian form and deriving the first order conditions produces

$$MRP\,(X_i) = \left[\frac{s_i - \lambda(1 - s_i)}{r - \lambda(1 - r)}\right] P_i$$

and

$$MRS\,(X_iX_j) = \left[\frac{s_i - \lambda(1 - s_i)}{s - \lambda(1 - s_j)}\right] \frac{P_i}{P_j}.$$

The first set of equations indicates share tenant farms are unlikely to utilize resources to the point where marginal revenue product is equal to factor price. The second set of equations suggests that share tenant farms will overcapitalize or undercapitalize by failing to produce at points of tangency between isoquants and isoexpenditure lines.

Both the generalized version of Heady's model and the alternative formulation of the optimal farm size problem indicate that share tenant arrangements are likely to lead to combinations of factor inputs that do not minimize cost of production. This tendency toward overcapitalization or undercapitalization by share tenant farms contradicts an implicit and important conclusion of Professor Heady's original model.

EDWIN F. ULVELING
Georgia State University

Reference

[1] HEADY, EARL O., "Optimal Sizes of Farms Under Varying Tenure Forms, Including Renting, Ownership, State, and Collective Structures," *Am. J. Agr. Econ.* 53:17–25, Feb. 1971.

OPTIMAL SIZES OF FARMS UNDER VARYING TENURE FORMS, INCLUDING RENTING, OWNERSHIP, STATE, AND COLLECTIVE STRUCTURES: REPLY

Edwin Ulveling has made some interesting and useful extensions to my earlier analysis. However, I believe his term "contradiction" is misleading. His are "extensions," not refutations, and many more can be made. I have made extensions paralleling his in other studies. I did not label them "contradictions" because they simply showed the outcome under other variants of real factor prices, relative output sharing, very particular objective functions or restraints, etc., for either the tenant or landlord. In fact, in the first draft of my article I showed that not only should $s_i = s_j$ for factor price shares if the tenant (or equally the landlord) were to prefer the same cost-minimizing input mix as an owner with unrestrained capital, but also that r_i must equal r_j for output shares if the same commodity mix and resource allocation is to prevail for rented farms. However, space restraints caused me to remove these details to cover aspects of cooperative farming.

We can extend the analysis in several dimensions. Ulveling emphasizes the input mix. Supposing that s_i might approximate s_j, for example, while r_i might deviate considerably from r_j (a case which prevails in the Cornbelt for small and coarse grains), a simple picture of the production possibilities is Figure 1A where $r_i = 0.5$ and $r_j = 0.3$. With a "net price ratio" for commodities indicated by linear isorevenue lines of given slopes, the optimal output mix (and volume of output, as another expression of size) differs among tenant (T), landlord (L), and owner (O) where O is the production possibility for a farm as a whole. However, if we set $r_i = r_j$ as in Figure 1B, the transformation curves will have the same slope (i.e., marginal rates of transformation) along the rays passing through the origin and the same product mix will be optimal for tenant, landlord, and owner.

I present the example to show that a good number of extensions can be illustrated (depending on what one wishes to analyze) and are hardly refutations of my earlier analysis in its particular context. Even for the example in Figure 1, one should carry the extensions further in terms of implied magnitudes of s_i and s_j and of "side effects" that the functions in 1A and 1B have an income redistribution between tenant and landlord.

Ulveling also uses some terms of interpretation which I do not see as either bothersome or having particular content. He suggests that my analysis is from the viewpoint of an owner leasing to a tenant. He mentions I derive optimum size from a landlord standpoint. However, in the analysis as presented, the conditions for a tenant are intuitively implied in discussions for a landlord and vice versa. I consider the analysis, within the context presented, applies similarly to both. Ulveling also poses the question of how farm size will actually be determined in the case of a share tenant. He then shows equilibrium conditions where the tenant imposes a restraint of assuring a minimum profit level to the landlord.

Is this the way farm size is determined by a share tenant? Getting down to actual "numbers of the real world," I doubt many tenants set up this restraint. (I simply have never seen any data to this

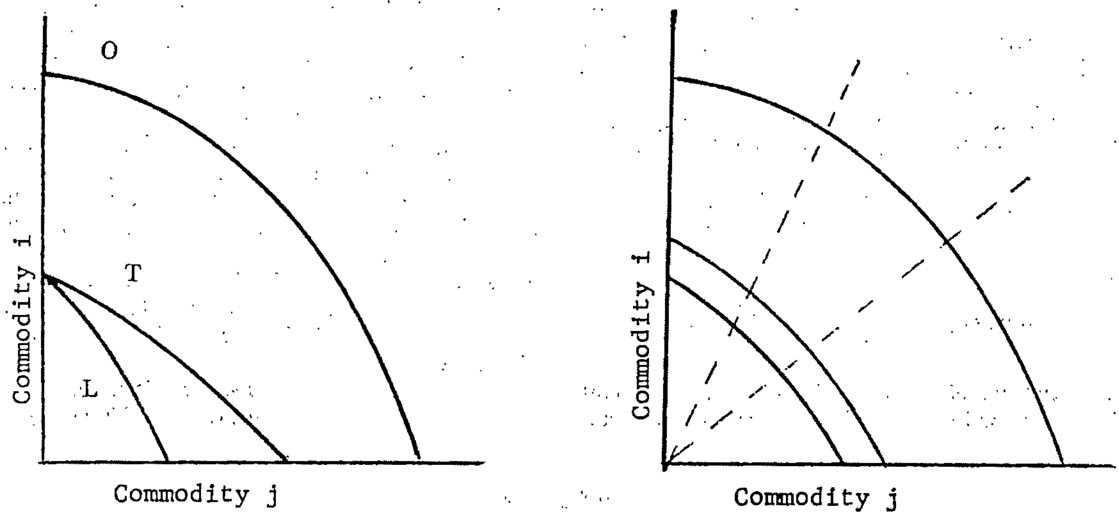

Figure 1. Optimizing conditions when $r_i \neq r_j$ (*A*) and $r_i = r_j$ (*B*).

effect, and I doubt that he has.) Using unquantified judgment, my guess is that share tenants suppose the landlord has incorporated his "fair profit" (or more) in the share rate he charges and optimizes accordingly. In this respect, Ulveling also suggests that this minimum profit restraint imposed by the tenant upon himself on behalf of the landlord is a more generalized form. In a literal sense of the real world (or even in terms of abstractions about it), I doubt that "generalized" is the correct terminology. Neither do I believe the term "contradiction" used in his last paragraph is appropriate. Again, he has made another useful extension. It is interesting but many more can be made; they can show or imply equilibrium size, factor combinations, and output mixes under variants of objective functions or restraints for either tenant or landlord. (However, they are not contradictions or even particularly generalizations of my analysis within the context of the presentation.) I will mention a few of the extensions still to be made. The landlord may effectively place a restriction in the lease that $r_jX_j \geq m_j$, or that the expected amount of a particular cash crop be a minimum (e.g., corn acreage must be at least 80). The tenant may, for uncertain reasons, restrain the minimum output level to $(1-r_i)X_j \geq m_j$ for a particular enterprise (e.g., dairy) and then optimize input and output mixes against this and other restraints. (Obviously, size per se will be affected by the magnitude of m_j.) Or, in a programming format, he may impose a restraint on output mixes that a minimum income flow, F_k, is generated in each month

$$\sum_{i=1}^{n} (1 - r_i)P_{ik}Y_{ik} \geq F_k(k = 1, 2, \cdots, 12)$$

where Y_{ik} is the amount of the ith commodity produced in the kth month. If we get into inter-year allocative and decision problems, the length of leases, planning horizons, resource transformation over time, etc., there is a host of other extensions to make. (Actually, in the references cited in my article, I have touched upon many of these, and some akin to Ulveling's situations.)

These income (and their corresponding profit) restraints also affect volume of various outputs and aggregative farm size. They illustrate the implied size outcomes when still more variants of restraints are inserted into the model or objective functions are modified. I could add many more for both factors and commodities. Each taken alone is hardly a refutation or generalization of another, the emphasis that Ulveling seems to make.

As mentioned before, Ulveling has made some useful and interesting extensions. He has done me a favor because I now have been able to list some extensions I was not able to incorporate in my earlier paper because of page restraints. Together, I am sure we could write a lengthy monograph covering the theory of all possible leasing and tenure variants.

EARL O. HEADY
Iowa State University

LOCATIONAL DISTRIBUTION OF AAEA MEMBERSHIP AND JOURNAL CONTRIBUTION*

Some segments of the AAEA membership are concerned with representation on the Executive Board. The current geographic dispersion of the AAEA membership and authors or co-authors of major articles in the *Journal* may be of interest to the profession.

An analysis was made of the U. S. membership as of Sept. 1, 1971. Of the 3,285 paid members (regular and junior) the eight midwestern states had 936 or 28.5 percent (Fig. 1). Illinois with 187 members had 15 more members than six of the southeastern states. California with 210 had only five fewer members than eight mountain states and only seven fewer than five plains states (excluding Texas). The six New England states with 110 members were exceeded in number by six states—California 210, Illinois 187, Michigan 119, Indiana 119, Iowa 117, and Minnesota 112.

Largest membership concentration is in the District of Columbia and the adjacent states with a total of 660 members. The D.C. area, the eight midwestern states, and California comprise 55 percent of the total membership.

Because of the membership distribution, many hypotheses can be advanced, such as neither a Southerner, New Englander, nor a Rocky Mountaineer can be elected to office unless two from his area are nominated for the same office. Or, a USDA man with the concentration of membership around Washington and USDA employes throughout the U.S. always wins. Experience, however, does not support such hypotheses. The southeastern states have had four presidents since 1950, while the USDA has had only three.

The proposal to establish a board with regional representatives would involve partitioning the U.S. to allow each member equal representation. This would make some areas so large a member would hardly feel he had any better representation.

I was on the committee which developed the present organizational structure, and the problem of board representation received long and serious study. The conclusion at that time was to elect the board and the president by popular vote. The nominating committee, although it is not required to, may consider such factors as geographic location, professional employment, etc., in addition to

* The investigation reported here is in connection with a project of the Kentucky Agricultural Experiment Station and is published (as Paper No. 71-1-128) with approval of the Director.

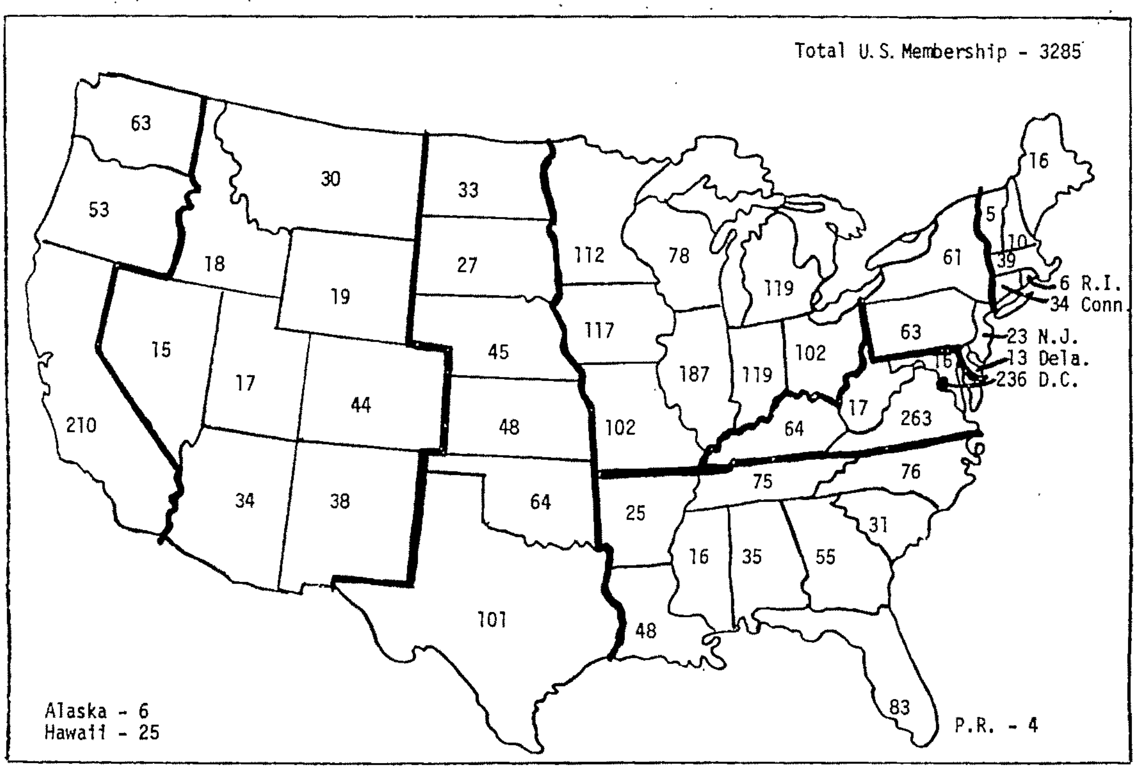

Figure 1. Distribution of AAEA membership, United States, September 1, 1971

other qualifications, in selecting nominees for office. The seriousness in which the various nominating committees in the past have approached their duty is quite impressive, and the results have substantiated this impression. Admittedly, the current system may not be perfect, but no better alternatives have been advanced.

A study was also made of the locational and membership distribution of authors or co-authors of major articles appearing in the *Journal* from February 1966 through August 1971, 28 issues, including the December Proceedings issues. Discussions, Notes, and Communications were not considered. There were 771 American and 67 foreign authors.

Considering both U.S. and foreign authors, there was one author in the 28 issues for each 3.92 members. At this rate, if every member had an article of equal quality, he would have *at most* one authorship every 22 years. Since the *Journal* receives articles from a much larger population than just AAEA membership, the time span is actually much longer. In the 28 issues examined between 25 and 30 percent of the authors of major papers were *not* AAEA members, with the exception of 1968 when the membership percentage jumped to more than 38 percent. On the assumption that 30 percent of the published articles continue to come from nonmembers, a member with equal quality articles could have one authorship every 31 or 32 years.

The *Journal* at present imposes no membership requirement on authors and probably should not, if the members are interested in having free access to new ideas. AAEA members do not possess a monopoly on ideas. However, a page charge imposed on authors would not only generate some income for the association but also would perhaps correct what some would regard as "inequity of support."

The eight midwestern states provided 276 of 771 American authors, or one author for each 3.4 members, while the eight mountain states had 30 articles, or one author for each 7.2 members. The nine southeastern states had 60 authors, or one for each 7.4 members. The six plains states (including Texas) had 76 authors, or one for each 4.2 members, while the six New England states had 20 articles, or one for each 5.5 members. The three Pacific Coast states had 83 authors, or one for each 3.9 members, and the four middle Atlantic states (including Delaware) had 64 authors, or one for each 2.5 members. Three states had no authors and eight had only one author in the 28 issues.

Agencies of the U.S. government had 136 authors in the 28 issues. No attempt was made to relate this to their membership in the AAEA.

It is obvious that productivity of articles varies from area to area and appears to be associated with the level of concentration of membership. Other factors such as size of research staff and level of professional training would be important factors in productivity evaluations.

JOHN C. REDMAN
University of Kentucky

Reviews

Capstick, Margaret, *The Economics of Agriculture*, New York, St. Martins Press, 1970, 163 pp. (Price unknown)

The purpose of this book is to provide students in economics with an introduction to the specific problems faced and/or created by the agricultural sector of a modern economy. The book was reviewed primarily as an aid to teaching an introductory course in agricultural economics. In this regard I think it is very useful. It uses basic economic principles to explain some of the economic phenomena one observes in the agricultural sectors of the United Kingdom, the European Economic Community (EEC), and the United States. It assumes that the student is already familiar with the basic concepts of economic theory although the author disregards this assumption at several points, e.g., in explaining the law of diminishing returns (pp. 20, 21) or the relationship of total revenue to the price elasticity of demand (pp. 65, 66). In comparison to the many recent editions of poorly integrated, disconnected, and uneven collections of readings, this book is a welcome edition because it avoids many of the formers' problems.

The first chapter is short, describing alternative types of organizations or production units in agriculture. It attempts to portray the dynamic character of agriculture by illustrating how both the spatial and temporal organization of agriculture are changing.

Chapter II examines the input side of agriculture at the firm level. The main point is that the institutions servicing agriculture have a considerable impact upon both the spatial and temporal allocation of the factors of production. Chapter III describes the character of the demand for agricultural products using the length of run and the marketing system as important factors affecting the character of the derived demand for farm products.

Chapter IV is devoted to the aggregate supply of agricultural products. The author begins with the assumption of perfect competition as a reasonable characterization of the aggregate supply for agricultural products. She proceeds to describe how the market is strongly influenced by external factors such as high fixed costs, joint products, technology, weather, and other uncertainties which make the aggregate supply much less responsive to price change than price theory would suggest, or which result in cyclical price patterns. The second half of this chapter is devoted to a discussion of methods of controlling agricultural supply. It is based on the author's argument that uncertainties in agriculture are such a major component of farmer decisions that programs which reduce uncertainty (e.g., price controls) will have a disproportionate effect on output. This chapter lays the groundwork for the final chapter (VII) on government programs in agriculture.

Chapter V is entitled "Agricultural Marketing." Its discussion centers around 4 questions:

1. How does the market function?
2. Are all the existing functions of the market necessary?
3. Is the marketing system efficient?
4. Does the producer receive a fair share of the consumer's dollar?

This is the weakest chapter in the book. It deals almost entirely with an analysis of marketing margins and farmers organizations such as cooperatives, attempting to improve the competitive structure of the input and output markets. It implicitly defines efficiency in terms of relative profits and size of margin while ignoring the myriad of other institutions and organizations such as storage, market news and information, grades and standards, and futures markets which are designed to improve market performance.

Chapter VI discusses international trade in agricultural products. It develops the historical background leading up to the present system of trade restrictions and then, relying on the student's knowledge of the principal of comparative advantage, explores the consequences of trade restrictions on producers and consumers.

The final chapter (VII) entitled "States and Farmers" is a discussion of governmental agricultural support policies and their impact on consumers, producers, and the rural society. It draws heavily upon the policies of the EEC, the United Kingdom, and the U.S. for its illustrations. It is a very useful but short chapter. The student would have profited from a more detailed economic comparison of the

goals of farm policies in individual European countries rather than just a short description of the EEC common agricultural policy and a slightly longer description of the agricultural policies of the United Kingdom and the U.S.

This is my main criticism of the book. It draws too heavily for its examples upon the United Kingdom, particularly in chapters IV through VI. The flyleaf states that the emphasis is on "the position of agriculture in the economies of western Europe and the United States." This leads the reader to expect breadth in the examples used to illustrate the discussion. Pragmatically, the criticism is of secondary importance since almost all equivalent books published in the U.S. concentrate entirely on the U.S. experience.

A minor criticism that detracts from the usefulness of the book is its lack of "finish" in such details as footnotes, support for its statements of fact, and clarity of the tables. In a number of places the book references are woefully incomplete. For example, on pages 34 and 155, the citations do not include the publisher, place of publication, or pages, making it very difficult for the interested reader to follow up. In other places (pp. 123, 124, for example) interesting statements of fact are presented with no citation as to the sources from which they were obtained.

In summary, in spite of minor problems, *The Economics of Agriculture* is a good supplemental reading. It uses economic concepts to explain problems and policies at a level the beginning student in economics can understand—once he has been exposed to these concepts in class. It would serve admirably as the springboard for small discussion groups in a beginning course in agricultural economics.

Rueben C. Buse
University of Wisconsin

Corden, W. M., *The Theory of Protection*, New York, Oxford University Press, 1971, xiii + 263 pp. ($8.00)

The title of this book is broader than its coverage. This work is intended to be the first of two volumes reviewing the main aspects of the theory of protection. The present book contains a restatement of the positive, static theory of protection, while the author plans to concentrate on the welfare aspects of protection in another book. The main emphasis here is on the effective protection concept. Professor Corden has been instrumental in developing and popularizing this theory; in this volume he explores some of the recent issues and questions concerning this concept.

Following the introduction (Chapter 1), the standard partial equilibrium theory of protection is presented in Chapter 2. Here it is assumed the domestic production of the protected product is vertically integrated. The reader familiar with trade theory will probably find this discussion rather dull; for others, it provides a foundation for the more sophisticated analysis of subsequent chapters.

The theory of effective protection is set out in Chapters 3 to 7. The general approach used by the author is to make numerous simplifying assumptions, relaxing and reinstating them throughout the book. Key elements of the effective protection concept in partial equilibrium terms are carefully presented, both graphically and algebraically, in Chapter 3. Here this analysis goes beyond the traditional tariff instrument; it allows for the existence of direct subsidies and taxes on the consumption or production of traded goods as well as a whole range of trade taxes and subsidies.

Chapters 4 and 5 develop the theory of protective structure in general equilibrium terms. Of particular interest is Corden's consideration of (1) the relationship between rankings of effective rates in a multiproduct model and the direction in which resources are pulled by the protective structure, (2) the possible effects of a protective structure on the outputs of non-traded goods, and (3) the balance of payments effects of a protective structure and the appropriate exchange rate adjustment to restore equilibrium.

In the following two chapters, some rather crucial assumptions of the foregoing analysis are relaxed. Chapter 6 focuses upon complications for the model arising from allowing substitution between various produced inputs and between these produced inputs and primary factors. One general conclusion is that in the presence of substitution, measured effective rates, based on input-output coefficients of the protection situation, are biased upwards. The analysis in Chapter 7 allows for the existence of non-traded produced inputs and non-infinite foreign elasticities for traded inputs and final goods. Once the key assumptions made in earlier chapters are relaxed, serious problems are presented for the effective protection concept and its usefulness in making predictions concerning resource allocation effects of a protective structure is reduced.

The remaining chapters of this book are not particularly germane to the core chapters on effective protection theory. Chapter 8, which involves a departure from the positive economics emphasis of the book, discusses the "uniform tariff issue," a concept which deals with determining the optimum tariff structure when there is no particular motive for fostering one type of industry more than another. Chapters 9 and 10 extend the analysis of the theory of protective structure developed in earlier chapters to quantitative import restrictions.

Corden's book contains a comprehensive theoretical discussion of the effective protection concept. He has carefully explored the complications for the theory resulting from removal of certain key simplifying assumptions. Nevertheless, the lengthy development of certain issues may be a bit trying for the impatient reader.

Larry J. Wipf
The Ohio State University

Halter, Albert N., and Gerald W. Dean, *Decisions Under Uncertainty with Research Applications*, Cincinnati, South-Western Publishing Co., 1971, iv + 265 pp. (Price unknown. Paper)

As for many other textbooks, "the authors' motivation for writing this book stemmed initially from the experience of attempting to teach a course . . . on *decision theory* and finding the available texts to be unsatisfactory. . . ." They desired "to carry students beyond a purely theoretical discussion of *decision theory* and into applications that have been made . . ." (p. iii) (italics added). In this reviewer's opinion they have been successful in producing the best available text for a course in applied decision theory.

Their success has, of course, been brought at a price. They have still had to spend the first half of their text on the standard decision theory topics of probability theory, derivation of utility functions, a prior and posterior distribution, and Bayesian decision making. They teach (sketch?) these topics more by well-discussed example than by axiom. They succeed, particularly in their discussion of the estimation of utility functions, in introducing a feel for real life research problems, which is notably missing from more formal texts. The second half of the book applies decision theory to five problems: (1) stocking rates with variable range feed availability, (2) choice of cropping program for an Imperial Valley farmer, (3) oil well drilling and financing, (4) make or buy decision for a forestry company, and (5) the value of climatological prediction.

The most notable omission is a serious discussion of modeling, and anyone using this text will need to discuss modeling seriously. This reviewer doubts whether many (maybe any) of the cited applications have very close relationship to the real world problem faced by decision makers. For instance, the first cow-calf operation example (for uncertain range conditions (p. 144)), invites the rancher to choose a cow herd size from the set {230, 280, 320, 360, 415, 460}, whereas it would appear to this reviewer that the set should be {any integer between 230 and 460}; and it would appear from interpolation (p. 154) that a herd size of about 395 would be at least 10 percent more profitable than the nominated "optimum" strategy of 415 cows. The same objection of "excessive discreteness" can be levied at the stocker cattle example (p. 157).

In an example of crop selection in the Imperial Valley (p. 172), the only restraints modeled refer to nematodes and marketing quotas; potential labor, machinery, and irrigation water bottlenecks are not modeled or even mentioned. In this case the quadratic programming solution procedure is "explained" simply by reference to the literature. In somewhat the same way, a decision tree is used (p. 210) to explain an oil exploration problem without even reference to the literature, as if this were a self-evident concept.

In short, the authors have gone a long way towards meeting the need for an applied text on decision theory. Nevertheless, an instructor using this text may, in due course, be motivated by the limited scope of this book to write an applied text on *decisions under uncertainty* including rather fuller discussions of modeling, quadratic, discrete stochastic, and dynamic programming, as well as evolutionary operations.

WILFRED CANDLER
Purdue University

Heady, Earl O., ed., *Economic Models and Quantitative Methods for Decisions and Planning in Agriculture*, Proceedings of an East-West Seminar, Ames, Iowa State University Press, 1971, xiii + 518 pp. ($10.50)

This volume contains the formal papers and discussions of an East-West Seminar held in Hungary in 1968. Six major areas were covered: the foundation and background of planning models, micro level problems and potentials, regional models, national models being developed or used, formulating national models, and the potential-performance gap and how to put models to better use for society. This volume has something to offer a variety of potential readers. It is probably advisable for the reader to sample various sections according to personal interests.

For an overview of procedures, the volume contains a number of fairly comprehensive survey articles. To the authors' great credit, these papers include a substantial amount of evaluation on strengths and weaknesses of different approaches and models.

On comparative analysis of models used in capitalist and socialist economies, two points: first, the common elements and problems are rather striking; second, one gets a glimpse in some depth, at least for the nonspecialist, and some critical evaluation of planning in various socialist economies. Some difficulties remain in interpreting the English translations. Thus, the record of informal discussions might prove especially useful, if and when it is published. The papers demonstrate the shift to decentralization and shadow prices as an allocating mechanism in socialist economies, along with the evidence of more planning in capitalist economies. These trends have led a number of commentators to suggest that the two major economic systems are evolving to be more alike.

Those readers interested particularly in the micro, regional, or macro level, can concentrate on the relevant major parts of the volume. Two words of guidance: (1) Scan the other sections because there is some overlapping, and (2) all will be interested in the final part on evaluation. Developments are probably furthest along at the firm level and these papers are able to draw the most evaluation from experience. At the other extreme, the national models are presented almost completely in descriptive form and as experimental models with less experience to evalu-

ate. J. Havlicek of Czechoslovakia undoubtedly struck a responsive note in many participants with his remark that national models "until now . . . relied heavily on the branches of techno-economical conceptions originating from the heavens, intuition and similar foundations . . ." (p. 343). Bergmann's comment on the subsequent Minsk Conference, that progress on management techniques was shown to exceed that on development of fully consistent theories [1, p. 557], applies to this proceedings also.

The overwhelming common denominator is linear programming, cutting across type of economy and all levels of aggregation. However, evidence of use and some evaluation of input-output, regression and trend procedures, a discriminant function, and forms of budgeting and the traditional socialist method of balances were found. A variety of other potential methods were described.

The problems of linking planning activities at various levels and of incorporating feedback from one level to another are discussed in the final chapters (and in parts of earlier chapters) from both socialist and capitalist viewpoints. Earl Swanson (p. 239 ff.) capsules an important theme: that a comprehensive optimizing model doesn't exactly fit the needs of either socialist or capitalist planners. Both require in the aggregation process a positive model at the micro or macro level to recognize the existence of the other level and provide feedback from it.

In assessing gaps between potential and present use of systematic planning procedures, Reisegg (p. 462) identifies two types of plans: (1) for decision making—those made for guidance of the "right" approach among alternative policies, and (2) for action —those made to be followed. In the latter, gaps are serious, and mathematical techniques have been used and evaluated primarily at the firm level. Planning for decision making has analytical objectives and is not necessarily tested against outcomes. Even the concept of gap is evasive.

Individual papers vary from concise and organized, to more rambling train-of-consciousness presentations. In some cases discussants chose to amplify areas not covered by a speaker rather than comment on his paper, but others did amplify and raise questions. Happily, the approach taken seems to bear little relation to the nationality of the speaker.

In sum, all the strengths and weaknesses of the symposium approach are present, but the balance is decidedly in favor of the former. The advanced planning, the topic, and the quality of speakers have resulted in a useful volume.

George D. Irwin
Economic Research Service, USDA at Purdue University

Reference

[1] Bergmann, Denis, "A Synoptic View," *Policies, Planning, and Management for Agricultural Development*, Papers and Reports of Fourteenth International Conference for Agricultural Economists, Minsk, USSR, Aug. 23-Sept. 2, 1970.

Howe, Charles W., and K. William Easter, *Interbasin Transfers of Water*, Baltimore, Johns Hopkins Press, 1971, xiv + 196 pp. ($9.50)

The Howe-Easter collaboration is a direct outgrowth of the identification of this topic by Resources for the Future in 1965 as a top priority issue in the water resources field. The authors were commissioned to do an arduous task, i.e., prepare a careful and scholarly analysis in specifying a conceptual framework for large-scale water transfers and assembling and developing empirical evidence which would relate to this framework. Moreover, identification of this area as one of top priority implied an objective of presenting the analysis in a form which would be persuasive to public decision makers. In the midst of increased public recognition of the existence of disparate regional water supplies and demands, the need for a careful identification of problems and evaluation of alternative solutions cannot be denied. Advocates of economic efficiency are indebted to RFF and to Howe and Easter for initiation and execution of this task.

According to the authors, their intent was "to sum up what is currently known about the direct and indirect benefits attributable to water, the potential costs of interbasin transfers, and the problems relating to such transfers; to present information on a range of alternatives to interbasin transfers; and to suggest methods of economic analysis appropriate to these large projects" (p. 1). In terms of appeal to resource economists, the interesting ordering of these items can probably be reversed. The research methodology appropriate for large-scale water transfers poses hordes of new problems, primarily messy empirical ones. To cite the authors, ". . . we have left the happy world of partial equilibrium analysis . . ." (p. 169). In particular, the national (as opposed to regional) benefits are seen to be crucially dependent upon forward linkages from agriculture (i.e., the extent to which certain regional industries are constrained by existing regional supplies of primary agricultural products), the degree of labor and capital immobility, and displacement and/or increased subsidization of agricultural output in other regions. The authors handle the first problem area on the basis of extreme assumptions—strong forward linkages and none at all. The analysis of labor and capital immobility utilizes Havemann-Krutilla models with respect to the occupational and regional incidence of unemployment and excess capacity.

The analysis of output-related effects concludes that increased production from reclamation lands has caused increases in commodity program payments (ranging from $16 to $468 per irrigated acre), stimulated regional shifts in production, and reduced incomes of non-reclamation farmers. The conceptual

basis for this analysis must be faulted in that reclamation lands are arbitrarily defined as producers of the marginal, price-depressing quantities. A more satisfactory framework would consider the effects of capital and labor inputs which the public sector also caused to be more plentiful and/or more productive.

The estimates of direct and indirect benefits of additional agricultural water are compiled from a variety of research endeavors, most of which are familiar to those interested in water economics. Direct benefits fall largely in the $10 to $20 per acre-foot range; total benefits range from $14 to $120 per acre-foot, the latter only under extreme resource immobility. The supply prices of alternative sources of water are less well known; thus, the assemblage thereof is a valuable service to the profession. Reduction of conveyance losses is identified as ". . . a very promising alternative" (p. 170); an amount of water about equal to that proposed in most Columbia-Colorado River transfers (9 million acre-feet per year) could be provided at $2 to $50 per acre-foot. Continued surface developments could provide 32 million acre-feet per year at $3 to $41 per acre-foot. Either alternative compares favorably with the $50 to $60 per acre-foot costs of the major interbasin transfer proposals.

If one is to be critical of the Howe-Easter effort, it must be for an (inherently) uneasy compromise in attempting to address both scholarly and public audiences through a single vehicle. As an example, the estimates of national benefits from a hypothetical in-transit diversion to Oregon range from $7 per acre-foot (no forward linkages, high employment, and resource mobility) to $130 per acre-foot (strong forward linkages, high unemployment, and resource immobility). Estimates of ranges are helpful to scholars, especially in light of many empirical unknowns. Administrators and legislators, on the other hand, want and deserve a stronger flavor of informed professional judgment than is generally contained herein. To cite an example, the nature of forward linkage as an empirical matter certainly needs more research and demands caution by academicians. The overall economic efficiency of currently proposed massive water diversions on the other hand, is subject to much less uncertainty; in current parlance, "... no way!" Howe and Easter should be commended on their contribution to the scholastic world, but urged to tender separate and stronger provocations to the world of decision makers.

JOE B. STEVENS
Oregon State University

Kuznets, Simon, *Economic Growth of Nations; Total Output and Production Structure*, Cambridge, Belknap Press of Harvard University Press, 1971, xii + 363 pp. ($15.00)

When it comes to new books, pygmies swamp the market, but here is a book by one of the few giants in the profession. It and *Modern Economic Growth*, Yale University Press, 1966, also by Kuznets, are fundamental in approaching economic growth. Economists who are seriously engaged in growth research can ill afford not to have both of them.

The book here under review is the up-to-date source of the findings of careful and competent inquiry pursued by Kuznets over many years. The analysis is predominantly quantitative. It shows clearly and cogently that modern economic growth is an exceedingly complex process. By implication it leaves little room for doubt that the recent plethora of economic growth models is not only simplistic but of little value as guides for empirical analysis. Theorizing with no empirical involvement has become a bane of economics as Professor Leontief argued in his American Economic Association presidential address, "Theoretical Assumptions and Nonobserved Facts."

With respect to economic growth, Kuznets' analysis strongly supports Leontief's assessment. A superficial reader of *Economic Growth of Nations* who has a vested interest in a particular growth model may find it convenient to believe the book consists of a vast array of facts without theory. But he would be misled in part no doubt because of Kuznets' professional taste not to parade his theoretical assumptions. The careful reader will discover them and see that they are rich in terms of analytical possibilities. Kuznets does take on W. W. Rostow's "take-off" theory (pp. 41, 42) and finds it wanting. He also sees little support for Alexander Gerschenkron's hypothesis on the advantages of "backwardness" (p. 42).

The book is built on the quantitative foundations of Papers I, II, and III that appeared in 1956, 1957, and 1958 in *Economic Development and Cultural Change* and on Kuznets' two Marshall lectures delivered at the University of Cambridge in 1969. Major new bodies of data are added, the estimates are updated, and the analytical parts are extended. The first two parts, pp. 1–99, are a classic treatment of levels and variability of the rates of growth and of growth productivity including nonconventional costs. The section on nonconventional costs represents a major extension in theory (by implication) and empirical analysis in accounting for the productivity gains that originate from the advances in knowledge, mainly in the sciences, and from the accumulation of human capital. Part VII, Summary and Interrelations, pp. 303–354, although long, in my judgment, does not do full justice to the analytical core of the book.

THEODORE W. SCHULTZ
The University of Chicago

Volin, Lazar, *A Century of Russian Agriculture: From Alexander II to Khrushchev*, Cambridge, Harvard University Press, 1970, vi + 644 pp. ($18.50)

The manuscript was nearly completed when the author died in late 1966 at the age of 70. A consider-

able amount of work was required, however, before the manuscript could be published, and it appears to have been done with care and thoughtfulness. With the deaths of Naum Jasny and Lazar Volin—the two emigre scholars from Russia who contributed so much to our understanding of agriculture both before and after the October Revolution—those of us who have an interest in such matters suffered an irreparable loss. While Jasny wrote with more passion and analytical insight that did Volin, Volin's work was always characterized by a combined sense of balance and a real sympathy for the plight of the Russian peasant, whether under the czars or the Communists. Together they taught us a great deal and it is not easy to see who will replace them.

The present book was almost certainly intended to be the capstone of Volin's distinguished career. It is a capstone of which he should have been proud, even in its somewhat incomplete state. The historical sweeep is a broad one with almost the first quarter of the book devoted to the rise of serfdom, the emancipation of the serfs, and the political, social, and economic development of agriculture from 1864 to the October Revolution. The remainder of the book deals with agriculture under the Communists.

The book can be described primarily as descriptive rather than analytical. This is not meant as criticism. There was obviously a concern for the importance of an event or a policy or a program since it was given space. The vicious elimination of the kulaks, the ruthlessness of the collectivization of agriculture, the horrible famine that official policy permitted—or caused—in 1932–34, the rationale for the functioning and demise of the Machine Tractor Stations (MTS), the slow growth of output through the Stalin era, and the economic exploitation of the peasant are all described in a way that is both accurate and informative.

Most of the last half of the book deals with Soviet agriculture "under Khrushchev." While conscious of the numerous errors and frequent turns and twists in agricultural policies under Khrushchev, Volin's general evaluation of Khrushchev was a sympathetic one. It is a view with which I am in agreement. Khrushchev was obviously an impetuous man, and this was revealed in many of his actions affecting agriculture. He was correct in calling for the abolition of the MTS, but failed to see the consequences of rapid destruction of an institution without having provided suitable alternatives. He was correct in calling for the expansion of the corn area, but badly overdid it. He was on the right track in reducing the area of summer fallow in the humid areas, but the effects were disastrous when applied to the dry areas. Nor did Khrushchev fully understand the benefits that could be derived from either unbiased agricultural research or extension, though he obviously knew something was wrong in the Soviet Union in both of these areas. On several occasions his own meddling was one of the things that was wrong.

But Khrushchev did understand that development of Soviet agriculture required major increases in farm prices and incomes. As Volin notes, state purchase prices for grain increased more than sixfold between 1952 and 1962 and the prices of livestock by fourteen times. There was relatively little change in the already high prices of the industrial crops, cotton and sugar beets, that had been so strongly favored under Stalin. Khrushchev was generally knowledgeable about and sympathetic to the problems of the farm population; he knew very well what was said or done in Moscow didn't always work out that way down on the farm. While Khrushchev can hardly be described as a libertarian, his condemnation of Stalin's reign of terror and the significant if not complete reins upon the secret police were not only major contributions to the Soviet populations, including the farm population, but also a personal benefit since he lived out his normal life—something that could not have been imagined before Khrushchev.

Unfortunately, most of the statistical information stops with 1962, only a few items being extended to 1964. We lose because Volin was unable to bring the material up through 1964, the end of the Khrushchev era.

This book is well worth the attention of any individual who wants background for understanding both the past and future of Soviet agriculture. It is a well-balanced presentation, noting both successes and failures. While it is no substitute for Naum Jasny's *The Socialized Agriculture of the USSR* in terms of the mass of detail and critical analysis presented therein, the two books together provide us with an amazing legacy.

D. Gale Johnson
University of Chicago

Books for listing in this section should be sent to the Book Review Editor (see inside front cover for address).

Books Received

Arthur, Henry B., *Commodity Futures as a Business Management Tool,* Boston, Division of Research, Harvard Business School, 1971, xiv + 392 pp. $10.00.

Besterman, Theodore, *Agriculture: A Bibliography of Bibliographies,* Totowa, N.J., Rowman and Littlefield, 1971, xiv + 302 pp. $15.00.

Capron, William M., ed., *Technological Change in Regulated Industries,* Washington, D.C., The Brookings Institution, 1971, xiii + 238 pp. $7.95.

Chamberlain, Neil W., and Donald E. Cullen, *The Labor Sector,* 2nd ed., New York, McGraw-Hill Book Company, 1971, ix + 676 pp. $12.50.

Chisholm, Roger K., and Gilbert R. Whitaker, Jr., *Forecasting Methods,* Homewood, Ill., Richard D. Irwin, Inc., 1971, xi + 177 pp. $3.95.

Dhrymes, Phoebus J., *Econometrics: Statistical Foundations and Applications,* New York, Harper and Row Publishers, 1970, xii + 592 pp. Price unknown.

Freeman, Donald B., *Rail Movement of Fruit in Queensland,* St. Lucia, University of Queensland Press, 1971, xvii + 107 pp. $6.20.

Gamble, S. H., *The Despensa System of Food Distribution,* New York, Praeger Publishers, 1971, xiv + 139 pp. $13.50.

Hayami, Yujiro, and Vernon W. Ruttan, *Agricultural Development: An International Perspective,* Baltimore, The Johns Hopkins Press, 1971, xiv + 367 pp. $10.00.

Ingram, James C., *Economic Change in Thailand 1850-1970,* 2nd ed., Stanford, Stanford University Press, 1971, ix + 352 pp. $10.00.

Intriligator, Michael D., ed., *Frontiers of Quantitative Economics,* Amsterdam, North-Holland Publishing Company, 1971, xi + 471 pp. $26.25.

Klatzmann, Joseph, Benjamin Y. Ilan, and Yair Levi, eds., *The Role of Group Action in the Industrialization of Rural Areas,* New York, Praeger Publishers, 1971, xxxiii + 599 pp. Price unknown.

Knight, Peter T., *Brazilian Agricultural Technology and Trade: A Study of Five Commodities,* New York, Praeger Publishers, 1971, xxii + 223 pp. $15.00.

Leagans, J. Paul, and Charles P. Loomis, eds., *Behavioral Change in Agriculture: Concepts and Strategies for Influencing Transition,* Ithaca, Cornell University Press, 1971, xii + 506 pp. $12.50.

Lele, Uma J., *Food Grain Marketing in India: Private Performance and Public Policy,* Ithaca, Cornell University Press, 1971, xviii + 264 pp. $12.50.

Levi, Donald R., *Agricultural Law,* Columbia, Lucas Brothers Publishers, 1971, xii + 329 pp. Price unknown.

Liu, Jung-Chao, *China's Fertilizer Economy,* Chicago, Aldine Publishing Company, 1970, xv + 173 pp. $6.00.

Ljungmark, Lars, *For Sale—Minnesota: Organized Promotion of Scandinavian Immigration 1866-1873,* Chicago, Swedish Pioneer Historical Society, 1971, viii + 304 pp. Price unknown.

Nelson, Richard R., T. Paul Schultz, and Robert L. Slighton, *Structural Change in a Developing Economy: Colombia's Problems and Prospects,* Princeton, Princeton University Press, 1971, xi + 322 pp. $12.50.

Olson, Sherry H., *The Depletion Myth: A History of Railroad Use of Timber,* Cambridge, Harvard University Press, 1971, xvi + 228 pp. $9.00.

Reichardt, Helmut, *Optimization Problems in Planning Theory,* Athens, Center of Planning and Economic Research, 1971, 79 pp. Price unknown. Paper.

Schultze, Charles L., Edward R. Fried, Alice M. Rivlin, and Nancy H. Teeters, *Setting National Priorities: the 1972 Budget,* Washington, D.C., The Brookings Institution, xix + 336 pp. $2.95 paper.

Seckler, David, ed., *California Water: A Study in Resource Management,* Berkeley, University of California Press, 1971, xiii + 348 pp. $15.00.

Steiner, Gilbert Y., *The State of Welfare,* Washington, D.C., The Brookings Institution, 1971, x + 346 pp. $7.50.

Strong, Ann Louise, *Planned Urban Environments,* Baltimore, The Johns Hopkins Press, 1971, xxxiv + 406 pp. $20.00.

Takayama, Takashi, and George G. Judge, *Spatial*

and Temporal Price and Allocation Models, Amsterdam, North-Holland Publishing Company, 1971, xx + 528 pp. $23.50.

Weitz, Raanan, *From Peasant To Farmer: A Revolutionary Strategy for Development*, New York, Columbia University Press, 1971, xvi + 292 pp. $10.00.

Westebbe, Richard M., *The Economy of Mauritania*, New York, Praeger Publishers, 1971, xviii + 173 pp. $15.00.

Williams, Donald B., *Agricultural Extension: Farm Extension Services in Australia, Britain and the United States of America*, Carlton, Australia, Melbourne University Press, 1968, xi + 218 pp. $7.75.

Yar-Shater, Ehsan, ed., *Iran Faces the Seventies*, New York, Praeger Publishers, 1971, xx + 391 pp. $12.50.

Announcements

1972 ANNUAL AAEA MEETING

The 1972 annual AAEA meeting will be held Aug. 20–23 at the University of Florida, Gainesville.

Dr. Kenneth R. Tefertiller, head of the UF Department of Food and Resource Economics, will be in charge of local arrangements. Suggestions or requests, including needs for space for committee sessions to be held before or after the meeting, should be sent to Dr. Tefertiller.

The program format for the annual meeting this year will be similar to that of 1970 and 1971. General sessions will be scheduled in the mornings and sectional meetings and seminars in the afternoons. Special organizational activities will be scheduled Monday evening; Tuesday evening will be reserved for the Fellows Address and awards. Included Wednesday morning will be a joint session and a post-conference workshop sponsored by the AAEA Education Committee.

Contributed papers sessions will be organized as subsections within subject matter areas of the seminar sessions. There is one departure from the previous formats; no limit has been placed on the number of contributed paper sections. Dr. Luther Tweeten of Oklahoma State University is general coordinator of the contributed papers sections.

Titles of contributed papers must be submitted to Dr. Tweeten by May 15, 1972, and manuscripts must be in his hands no later than July 1st.

Papers presented at the general session and sectional meetings and major seminar papers will be published in the 1972 Proceedings issue (December 1972 AJAE). Papers in subseminars, including contributed papers sections, will be presented by title and author only in the Proceedings issue. Authors of subsession invited and contributed papers may submit their manuscripts to the AJAE for possible publication. Such papers will be subject to standard editorial review.

More detailed information on the program will be available soon in the form of a presidential newsletter..

UNDERGRADUATE DEBATE, PUBLIC SPEAKING, AND ESSAY COMPETITIONS

Competition is open to any undergraduate student interested in agricultural economics. Participants are encouraged to become members of chartered student-section affiliates of the American Agricultural Economics Association, but such membership is not required to enter the various contests. No individual student may enter both the debate and the public speaking competitions in the same year.

Public Speaking Competition

The public speaking may be on any topic in the area of agricultural economics. Each speech will be limited to 10 minutes' duration.

Chartered chapters or individuals must declare their intention of participating in the public speaking competition by writing *no later than June 1, 1972,* to Dr. John Sjo, Chairman, AAEA Student Activities Committee, Department of Agricultural Economics, Kansas State University, Manhattan, Kansas, 66502.

Debate Competition

The topic to be debated in 1972 will be announced directly to all the departments.

A declaration of intention to participate in the debate competition must be made in writing *no later than June 1, 1972,* at the address given above. Names of contestants and/or alternatives and coaches, along with the mailing address of each, should be included. No more than one debate team from one school may participate in the debate contest.

Student Essay Contest

The essay contest does not require attendance at the AAEA's annual summer meeting. It was developed primarily to provide an opportunity to participate for students who find it impossible to attend the annual meeting and for students whose abilities and interest tend to be in research and/or writing. The

development and preparation of a manuscript for purposes of publication is one of the objectives of this contest. Essays may deal with any topic in agricultural economics, agricultural industries, or rural sociology. The 1972 award paper will be published in the 1972 Proceedings issue.

Manuscripts should not exceed 2,500 words in length and should be prepared according to the instructions appearing on the inside back cover of the *American Journal of Agricultural Economics.* Manuscripts must be submitted in *triplicate* by *July 1, 1972,* to Dr. John Sjo, Department of Agricultural Economics, Kansas State University, Manhattan, Kansas 66502.

NAME CHANGE

Michigan State University's Rural Manpower Center has been changed to the Center for Rural Manpower and Public Affairs. Funds from the Kellogg Foundation and the U.S. Department of Labor are providing partial support.

INTERNATIONAL ASSOCIATION OF AGRICULTURAL ECONOMISTS 1973 CONFERENCE

Sao Paulo, Brazil, is the site for the next conference of the International Association of Agricultural Economists scheduled for Aug. 19–29, 1973. Conference meetings are tentatively set for a new international center now under construction in Sao Paulo. Should the center not be completed in time, an alternate site at one of the universities will be selected.

RESEARCH FELLOWSHIPS IN FOREST RESOURCES

Research fellowships in forest resources, with stipends up to $15,000, are awarded annually by Harvard University from the Charles Bullard Fund.

The one-year, usually non-renewable fellowships are available to men in public service, academic careers, and private forestry. Although preference is normally given for those in academic careers to holders of doctoral degrees, others whose projects show promise of important contributions to forestry, broadly defined, will be considered in terms that a year's study at Harvard will help fulfill this promise.

Statements describing an applicant's professional career to date, proposing a research and/or study program at Harvard, and evaluating this program in terms of its contribution to the applicant's future professional career, along with a comprehensive personal data sheet and any official college/university transcripts, should be sent to:

Committee on the Charles Bullard Fund for Forest Research
Littauer Center 119
Harvard University
Cambridge, Massachusetts 02138

News Notes

UNIVERSITY OF ALBERTA, CANADA

APPOINTMENT: **Milburn L. Lerohl,** Ph.D. Michigan State, research director, Agricultural Economics Research Council of Canada and visiting professor.

LEAVES: **Leonard Peter Apedaile,** as senior economist, to the Ministry of Rural Development, Government of Zambia, under contract of the Canadian International Development Agency, for two years; **Harold C. Love,** as visiting professor of agricultural economics, University of Science and Technology, Kumasi, Ghana, under contract of the Canadian International Development Agency, for two years; **Allan A. Warrack,** Minister of Lands and Forests, Government of the Province of Alberta.

UNIVERSITY OF ARIZONA

LEAVE: **Maurice M. Kelso,** professor emeritus, as visiting professor, Oregon State, fall quarter 1971.

UNIVERSITY OF CONNECTICUT

APPOINTMENT: **Carlos D. Stern,** Ph.D. Cornell, assistant professor.

CORNELL UNIVERSITY

AWARDS: **Joseph B. Bugliari,** professor of agricultural and business law, was awarded the Professor of Merit Award for outstanding undergraduate teaching, by the seniors of the College of Agriculture and Life Sciences.

ECONOMIC RESEARCH SERVICE, USDA

(EDD is Economic Development Division; ESAD is Economic and Statistical Analysis Division; FDTD is Foreign Development and Trade Division; FPED is Farm Production and Economics Division; FRAD is Foreign Regional Analysis Division; MED is Marketing Economics Division; NRED is Natural Resource Economics Division; SRS is Statistical Reporting Service.)

APPOINTMENTS: **Verel Benson,** MED; **Lon Cesal,** EDD; **William Crosswhite,** NRED; **James Driscoll,** MED, Kansas City, Mo.; **Richard J. Edwards,** USDA liaison to University of Tennessee, Nashville; **Kenneth R. Farrell,** deputy administrator, ERS; **Bruce M. Graham,** deputy administrator and chairman of the Crop Reporting Board, SRS; **Bruce L. Greenshields,** FRAD; **Wade F. Gregory,** assistant to the director, FDTD; **William H. Ragsdale,** FRAD; **Richard Raulerson,** MED, Athens, Ga.; **Joseph F. Schmidt,** EDD; **James R. Scullen,** FRAD; **Robert L. Tontz,** chief, Trade and Statistics Bureau, FDTD; **Larry Traub,** MED; **Rodney Walker,** FPED; and **Eldon Weeks,** chief, Farm Income Bureau, ESAD.

TRANSFERS: **Terry Barr,** ESAD, to Washington, D.C.; **Nelson L. Bills,** EDD, to Washington, D.C.; **Don Bostwick** and **Thomas L. Browning,** FPED, to St. Paul, Minn.; **William D. Crowley,** FPED, to Fort Collins, Colorado; **Stan G. Daberkow,** EDD, to Davis, Calif.; **Milton Ericson,** FPED, to Washington, D.C.; **James A. Evans,** FPED, to Pullman, Washington; **Ralph Forsht,** NRED, to Washington, D.C.; **Warren R. Grant,** FPED, to College Station, Tex.; **Milton Holloway,** NRED, to Pullman, Wash.; **Preston LaFerney,** MED, to Washington, D.C.; **Edgar Lee Lewis,** EDD, to Washington, D.C.; **Walter G. Miller,** to EDD from NRED; **Jim Naive,** to ESAD from FRAD; **William Pietsch,** NRED, to Denver, Colorado; **Leroy Quance,** NRED, to Washington, D.C.; **Jesse Russell,** NRED, to Experiment, Ga.; **Lynn Sleight** and **Larry Summers,** MED, to Washington, D.C.; **Charles W. Walden,** EDD, to Gainesville, Fla.

RESIGNATIONS: **George Bullion,** MED; **Bob Davis,** FPED; **John Droge,** MED; **Richard D. Duvick,** FPED; **Delmer Helgeson,** MED, Lincoln, Nebraska; **Lynn Pollnow,** NRED; **Charles R. Shumway, Jr.,** FPED; **Peter Smith,** MED, Albany, Calif.

RETIREMENTS: **Raymond P. Christiansen,** FDTD, director; now with the World Bank; **Mary S. Coyner,** FRAD.

LEAVE: **Fred Nelson,** ESAD, has returned from a study leave at the University of Minnesota.

UNIVERSITY OF FLORIDA

APPOINTMENTS: **Christopher O. Andrew,** formerly with the University of Nebraska Mission in Colombia, associate professor; **James A. Brown, Jr.,** M.S. Georgia, assistant professor in resource development, at Live Oak, Fla.; **George R. Perkins,** Ph.D. Michigan State, assistant professor; **Joseph H. Stafford,** formerly of Massachusetts Institute of Technology, director of Planning and Budgeting, and associate professor; **Melvin Louis Upchurch,** formerly administrator of ERS, USDA, Washington, D.C., professor; **Glenn A. Zepp,** ERS, USDA, stationed at Gainesville, Fla., assistant professor.

LEAVE: **J. Kamal Dow,** assistant professor, Chief of Party for the Ecuador/UF contract, Quito, Ecuador, for two years.

RESIGNATION: **Wallace Kenneth Boutwell,** formerly associate professor and assistant dean of Faculties for Research and Planning, to Florida Department of Education, Board of Regents, Tallahassee, as director of Planning and Evaluation.

UNIVERSITY OF IDAHO

APPOINTMENT: **Richard W. Schermerhorn,** Oklahoma State, as head of the Department of Agricultural Economics.

UNIVERSITY OF ILLINOIS

LEAVES: **J. M. Holcomb,** six-month sabbatical ending Dec. 31, 1971; **N. G. P. Krausz,** sabbatical, first semester, 1971–72 academic year; **J. T. Scott, Jr.,** six-month sabbatical, ending Feb. 29, 1972; **E. E. Broadbent,** with the United Nations Economic Commission for Africa, Addis Ababa, Ethiopia, until approximately mid-1973; **V. I. West,** dean of Agriculture, Njala University College, University of Sierra Leone, West Africa, to Sept. 1, 1973.

RETURN: **M. M. Wagner,** associate professor, returned from a two-year assignment as visiting professor at Uttar Pradesh Agricultural University, Pant Nagar, India.

IOWA STATE UNIVERSITY

APPOINTMENT: **Iftikhar Ahmed,** research associate in economics.

LEAVE: **Karl A. Fox,** Distinguished Professor and Head of the Department of Economics, visiting professor at the University of California-Santa Barbara and researcher for the National Science Foundation at the University of California-Berkeley, October through December, 1971.

UNIVERSITY OF KENTUCKY

LEAVE: **Russell H. Brannon,** associate professor, to Khon Kaen, Thailand, with the Kentucky/AID team.

RESIGNATION: **Zack C. Saufley,** extension marketing specialist, to the Farmers Bank and Trust, Frankfort, Ky., as vice president.

RETIREMENT: **John H. Bondurant,** professor, after 40 years of service.

UNIVERSITY OF MANITOBA, CANADA

APPOINTMENTS: **J. Clayton Gilson,** formerly head of the Department of Agricultural Economics, vice president of Research, Graduate Studies, and Special Assignments; **Arthur W. Wood,** formerly acting department head, head of the Department of Agricultural Economics.

LEAVE: **J. A. MacMillan,** adjunct professor, to become associate director, Alberta Human Resources Research Council, Edmonton, Alberta.

MEMPHIS STATE UNIVERSITY

APPOINTMENT: **Roger K. Chisholm,** associate professor of economics.

MICHIGAN STATE UNIVERSITY

APPOINTMENTS: **Colette Moser,** Ph.D. Wisconsin, assistant professor, manpower economics emphasis; **Derek Byerlee,** Ph.D. Oregon State, assistant professor, international program emphasis; **David Dunlop,** instructor, international program emphasis.

UNIVERSITY OF MINNESOTA

HONOR: **John D. Helmberger,** one of six Minnesota professors to receive the Horace T. Morse Award, provided by Standard Oil Foundation, in recognition of outstanding contributions to undergraduate education, selected from nominations by students and faculty, by the All-University Council on Liberal Education.

UNIVERSITY OF MISSOURI

APPOINTMENTS: **C. Brice Ratchford,** vice president for Extension, as president of the University of Missouri; **Jerry Looney,** instructor in agricultural law.

LEAVE: **Melvin Blase,** sabbatical to Midwest Universities Consortium for International Activities, Michigan State; **Stanley Johnson,** Department of Economics, Purdue, 1 year.

RESIGNATION: **V. Alonzo Metcalf,** professor, to Arizona State, as vice president for administration.

NORTH DAKOTA STATE UNIVERSITY

APPOINTMENTS: **Delmer L. Helgeson,** associate professor in agricultural economics; **William C. Nelson,** assistant professor in agricultural economics; **Donald M. Senechal** and **Donald E. Thomson,** assistants in agricultural economics.

OKLAHOMA STATE UNIVERSITY

APPOINTMENT: **Darryl D. Ray,** Ph.D. Iowa State, assistant professor.

Honor: **Luther G. Tweeten,** promoted from professor to regents professor, the third person in the university's history to receive such an appointment.

SOUTHERN ILLINOIS UNIVERSITY

Appointment: **Raleigh Jobes,** doctoral candidate, Oklahoma State, to teach introductory farm management.

Leave: **Gordon Langford,** assistant professor, to Santa Maria, Brazil, to work in agricultural economics with the SIU contract team.

TEXAS A&M UNIVERSITY

Appointments: **Peter J. Barry,** Ph.D. Illinois; **Conrad Fritsch,** Ph.D. Cornell, and **Ronald Kay,** Ph.D. Iowa State, assistant professors of agricultural economics; **William J. Vastine,** Ph.D. Ohio State, extension economist in food distribution.

Awards and Honors: **Clive R. Harston,** named to the three-member reviewing jury of the University of Buenos Aires, Argentina, to select and recommend staff for the university's newly formed Department of Agricultural Economics; **Alvin B. Wooten,** designated an Outstanding Educator of America.

UNIVERSITY OF WISCONSIN

Appointments: **Duncan A. Harkin,** director of the Center for Resource Policy Studies and Programs; **Harlan G. Hughes,** Ph.D. Missouri, assistant professor of agricultural economics in farm management.

OTHER APPOINTMENTS

Anthony Ballman, M.S. Missouri, Production Management Department, Moorman Manufacturing Company, Quincy, Ill.

Bill Blakeslee, M.S. Missouri, vice president for fluid milk marketing, Mid-America Dairymen, Inc., Springfield, Mo.

Ralph E. Cotterill, Michigan State, Economics Branch, Canada Department of Agriculture.

Robert Freman Glenn, M.S. Missouri, assistant professor, Southwest Missouri State College, Springfield.

Robert M. Head, M.S. Arkansas, manager, Federal Land Bank Association, Nashville, Arkansas.

Aida Recto Librero, Ph.D. Minnesota, assistant professor, University of the Philippines, College, Laguna, Philippines.

Ashley Lovell, Ph.D. Missouri, assistant professor, Tarleton State College, Stephenville, Texas.

George D. N. Lowe, M.S. Wisconsin, senior scientific officer, Land Resources Division, Overseas Development Administration, Surbiton, Surrey, England.

Harold Loyd, Ph.D. Missouri, assistant professor, Abraham Baldwin College of Agriculture, Tifton, Ga.

Noel K. Morris, M.S. Missouri, area farm management agent, University of Missouri Extension System.

Charnchai Musignisarkorn, M.S. Wisconsin, economist, Department of Economic Research, Bank of Thailand, Bangkok.

Glenn Nelson, Michigan State, economist, Office of Economic Opportunity, Washington, D.C.

Steve Newcom, M.S. Missouri, Trust Department of the Continental Illinois Bank and Trust Company, Chicago.

Fred Obermiller, Ph.D. Missouri, Minuteman Graduate Education Program, South Dakota State, Rapid City.

C. Wesley Randell, M.S. Missouri, foreign market development, American Soybean Association, Hudson Falls, Iowa.

John E. Reynolds, associate professor, Florida, assistant dean of the College of Agriculture.

Refugio Rochin, Ph.D. Michigan State, assistant professor, Department of Economics, University of California, Davis.

Michael Schwartz, Ph.D. Florida, has accepted an assignment with the Ecuador/UF contract in Quito, Ecuador, for 18 months.

Richard R. Sherlock, Michigan State, economist, Department of Agriculture, Rotorcea, New Zealand.

William Staub, Ph.D. Missouri, Economic Development Branch, ERS, USDA, Washington, D.C.

Jai Myung Suh, M.S. Missouri, College of Business and Economics, Yonsu University, Seoul, Korea.

Steve Van Meter, M.S. Missouri, Loan Applications Department, Connecticut Mutual Life Insurance Company, Hartford.

OBITUARIES

Carl C. Farrington, 66, deputy administrator of Commodity Operations, Agricultural Stabilization and Conservation Service, USDA, died in September, 1971. He worked in commodity operations for both government and private industry.

His first early government posts included assistant to the administrator of the AAA, vice president of the Commodity Credit Corporation for grain, cotton, rice, tobacco, and other commodity programs. He left USDA in 1948 to manage the grain division of Archer-Daniels-Midlands Company in Minneapolis. He served as a director of this firm from 1949 to 1960 and became vice president for development in 1960. In 1969 he was appointed ASCS deputy administrator for Commodity Operations, a post he held at the time of his death.

Special assignments Farrington held include membership on the Interim National Agricultural Advisory Commission in 1953 and the National Advisory Commission on Food and Fiber in 1966. He also served on an international task force on

emergency food reserves of the United Nations Food and Agricultural Organization.

He was a former president of the Terminal Elevator Grain Merchants Association, chairman of the National Grain Trade Council, director of the Grain and Feed Dealers National Association, director of the U.S. Feed Grains Council, and chairman of the Agricultural Committee of the Millers National Federation.

Born in Hydro, Oklahoma, Feb. 22, 1905, he received his bachelor's and master's degrees from Oklahoma State and did further graduate work at American University.

B. Russell Robertson, 60, Extension Marketing Specialist, University of Kentucky, died in September 1971. During his career with the Kentucky Extension Service he developed and conducted extension marketing programs with dairy, grain, and fruit and vegetable marketing firms and producers. He worked extensively with Kentucky farm organizations, marketing cooperatives, and agribusiness firms. His expertise in cooperative organization and management was well known throughout the Southeast. He was instrumental in the growth and development of several agricultural marketing cooperatives.

Robertson served on the Southeastern Dairy Marketing Committee and the Southeastern Extension Marketing Committee, was executive program advisor to the National Produce Market Managers Association, past chairman and regional director of the Dairymen's League Cooperative and president of the Midwestern Extension Consumer Education Association. He was a member of the American Agricultural Economics Association and the National Produce Market Managers Association.

Born and reared on a farm near Rushford, New York, Robertson received his Certificate in Marketing from Cornell University in 1935. He returned to his farming enterprise for several years prior to entering the University of Maryland where he received a B.S. in agriculture in 1953 and a M.S. in agricultural economics in 1957, at which time he joined the Kentucky Extension Service.

Robert B. Tootell, governor of the Farm Credit Administration for 15 years until his 1969 retirement, died Aug. 20, 1971, in Washington, D.C., of heart failure following major surgery at Georgetown University Hospital.

Under his leadership, farmer and rancher members became the sole owners of the Farm Credit System, which is supervised by the Farm Credit Administration (FCA). As an internationally recognized authority on agricultural credit, Tootell under the auspices of the Agency for International Development conferred with officials of many countries, including Iran, Kenya, and Ethiopia, about their credit problems. Since his retirement from the FCA, he had served as a consultant to the Farmers Home Administration.

A Montana farm boy, Tootell graduated from Montana State College in 1927, receiving his M.S. in agricultural economics from the University of California in 1931. He was awarded an M.P.A. in 1950 and an honorary L.L.D. in 1956 from Montana State.

He served in various capacities with the Federal Land Bank of Spokane and the Farm Credit Administration from 1934 to 1943. From 1943 to 1954 he was successively head of the Department of Agricultural Economics and director of extension at Montana State College and director of extension at Washington State.

Tootell is survived by his widow Helen, two sons, Robert, Jr., and Donald, and four grandchildren.

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Demand for Financial Assets in the Farm Sector: A Portfolio Balance Approach*

JOHN B. PENSON, JR.

The demand for financial assets in portfolios of farm business-household units is viewed as a problem of maximization of utility derived from pecuniary and nonpecuniary services provided by portfolio components and unused credit reserves. The statistical model provides simultaneous equations estimates of structural demand equations for commercial bank deposits. Yields on equities, marketable government bonds, and time and savings deposits as well as the service charge rate on demand deposits are shown to be important determinants of demand. The speed of adjustment of actual stocks to desired levels was estimated and comparisons were made with published estimates for other sectors.

THE theory of portfolio balance suggests that the desired balance between physical and financial assets in portfolios depends upon the relative pecuniary and nonpecuniary services and hence, utility provided by these assets. It has been suggested recently that the stock of unused credit reserves also provides a flow of specific nonpecuniary services to the farm business-household units comprising the farm sector. These units, in choosing between investment alternatives, will presumably desire that balance between financial and physical assets *and* liabilities which maximizes the utility derived from pecuniary and nonpecuniary services. However, the decision to invest in time deposits, for example, is not made independently of decisions regarding other financial assets or of decisions regarding physical assets and liabilities in the portfolio. The demand for a particular financial asset, therefore, is hypothesized to depend upon the pecuniary rates of return on this and other financial assets providing similar nonpecuniary service flows, the level of transaction balance requirements, and the units' demand for physical assets and liabilities.

The purpose of this paper is to test empirically the validity of the theory of portfolio balance as it applies to the demand for those financial assets most often included in definitions of "money": currency, demand deposits, and time and savings deposits at commercial banks. Perhaps the most widely accepted definition of money is that of demand deposits and currency, or M_1 balances as defined in the literature of the Federal Reserve System. Latané [15], among others, has justified the use of this definition, in part, on the grounds that these are the only two assets which function directly as a medium of exchange. Friedman and Meiselman [8, p. 182], in defining money as M_2 balances (M_1 balances plus time and savings deposits at commercial banks), argue that the appropriate reason for including time and savings deposits is that " . . . they are such close substitutes for other monetary items that it is preferable to treat them as if they were *perfect substitutes* rather than omit them." Instead of arbitrarily accepting either of these definitions, one can estimate separate demand equations for each financial asset, including as regressors in these equations the pecuniary rates of return on these assets as well as other nonmarketable and marketable financial assets in the portfolio. Explicit determination of the substitution relationship between these financial assets may reveal policy implications for monetary authorities concerned with the effect of their actions on the farm sector. The extent to which marketable government securities, for example, are a substitute for commercial bank deposits in portfolios of farm business-household units would indicate the potential effectiveness of open market operations as an indirect tool for monitoring the rate of loan expansion at farm sector-oriented commercial banks.

The stock of financial assets and unused credit reserves is shown in the first section of this paper to be analogous to the flow of particular nonpecuniary services and hence, utility to the farm business-household units. The conceptual model presented in the second section is similar to the work done by Tobin [24] and Hamburger [9, 10]. The conceptual model

* I would like to thank C. B. Baker, W. W. McMahon, M. J. Hamburger, W. McD. Herr, D. A. Lins, and G. D. Irwin for comments on earlier drafts or on empirical results. They are absolved of responsibility for any remaining errors. The views and conclusions presented in this paper are not to be attributed to the USDA.

JOHN B. PENSON, JR. *is an agricultural economist with the Farm Production Economics Division, Economic Research* Service, *USDA, stationed at the University of Illinois.*

shows the simultaneity of the substitution relationship between the demand for financial assets on the one hand and the demand for physical assets and liabilities on the other.[1] In addition, this section suggests that the speed of adjustment of actual stocks to desired levels be determined. The empirical approach outlined in the third section, however, is believed to be somewhat unique. This section discusses the corresponding statistical model for the financial assets empirically tested in this paper as well as the data employed and the simultaneous estimation procedure used. The present investigation will be limited to testing empirically the year-end demand for demand deposits and time and savings deposits at commercial banks due to data limitations discussed below. The fourth section presents the empirical results, while the fifth and concluding section discusses their policy implications.

Utility Maximization

Assume for the moment that the goal of the farm business-household unit is to arrange its portfolio of assets and liabilities in such a way that the utility of the unit will be maximized, and that this multiperiod utility function includes the pecuniary and nonpecuniary service flows to the unit.

There are several sources of utility available to the farm business-household unit. Hammer [12] specifies a utility function for manufacturing firms that includes only pecuniary returns. Perhaps a less well-known but nonetheless important source of utility to the unit is the nonpecuniary service flows provided by particular subgroups of assets. Feige [7], for example, views the demand for stocks of financial assets as being analogous to the demand for those flows of nonpecuniary services provided by the ownership of this particular subgroup of assets. McMahon [17] suggests that stocks of financial and physical assets yield a flow of nonpecuniary services and hence utility to the consuming unit.[2] Finally, Baker [2] suggests that unused credit reserves, though not an asset in the usual balance sheet accounting scheme, provide a liquidity service to the unit through its provision of potential access to financial assets without requiring actual disposal of the asset itself.[3] The flow of nonpecuniary services provided by particular groups of assets and unused credit reserves has a *direct* bearing on the desired portfolio balance in the farm sector. The foundation of this stock-flow relationship is reviewed below. The review is limited to those nonpecuniary flows of liquidity and related services to the farm business-household unit.

Service flows from financial assets

The nonpecuniary service flow provided by ownership of financial assets is comprised of s number of services. These services include such items as the high disposal liquidity premium associated with financial assets, defense against misfortune, the convenience of having wealth available as a means of payment in the instance of currency and demand deposits, and the safety of financial assets relative to other stores of value. Feige [7] and McMahon [17] have shown that this particular nonpecuniary service flow can be approximated by[4]

$$(1) \qquad \sum_{j=1}^{s} X_{ijt} = Sfa_{it-1} + Ifa_{it} = Sfa_{it}$$

where $i = 1, \cdots, c, dd, td, \cdots, f$ and $j = 1, \cdots, dl, \cdots, s$. This equation assumes that

[1] It is assumed for ease of exposition that all financial assets owned by farm business-household units provide similar "disposal liquidity" service flows.

[2] Portfolio balance preferences of the "consuming" farm business-household unit can be divided into at least two categories: (1) those for farm business reasons and (2) those for farm household reasons. Any investigation of the aggregate portfolio balance preferences of this unit must combine elements of both consumer and business behavior. Farm-oriented assets and liabilities of nonfarm landlords are included in the coverage of assets and liabilities in the portfolio of the farm business-household units, thus broadening the decisions concerning portfolio balance to include landlord-tenant behavior.

[3] Credit is defined in this paper as the borrowing capacity of the farm business-household unit.

[4] Description of the notation used:

- X_{ijt} = the jth nonpecuniary service flow provided by the ith financial asset in time period t.
- Sfa_{it-1} = the stock of the ith financial asset at the end of the previous period.
- Ifa_{it} = net investment in the ith financial asset during the period (net increase in holdings of the ith financial asset during the period minus depreciation, which is zero in the case of nonmarketable financial assets).
- c = currency.
- dd = demand deposits at commercial banks.
- td = time and savings deposits at commercial banks.
- dl = the disposal liquidity premium.
- f = the number of different species of financial assets held.
- s = the number of different nonpecuniary services provided.

the flow of nonpecuniary services to the farm business-household unit can be measured by the number of dollars required to purchase this nonpecuniary service flow per unit of time. This flow, as shown above, will be adjusted by the amount of current net investment over time.

Service flow from unused credit

Tobin [25, p. 66] states, "The theory of liquidity preference does not concern the choices investors make between the whole species of monetary assets, on the one hand, and other broad classes of assets, on the other." It is his contention that liquidity preference theory takes as given the choices determining how much of total wealth should be invested in financial assets, and concerns itself with the allocation of this amount among demand deposits, currency, and other financial assets. Davidson [5, p. 302] argues that "... since for physical assets l" [the disposal liquidity premium] "is normally very small ... as compared to the liquidity premiums associated with the claims (financial assets) to capital goods, claims will normally be preferred to the capital goods as a store of value."

Only a portion of the liquidity services available to the farm business-household unit may be observed if the view here of disposal liquidity is restricted as are Tobin's and Davidson's. Baker [2, p. 507] states, "Unused credit, like balance sheet assets that are liquid, constitute a reserve of liquidity that can be called upon to counter the effects of failure in expectations."[5] Thus, unused credit reserves provide certain nonpecuniary service flows not much unlike those provided by financial assets. These services would include such items as a "credit" liquidity premium and defense against misfortune. This service flow has the added advantage of not requiring actual disposal of the income-earning asset when the need for demand deposits actually arises. The aggregate value of this nonpecuniary service flow can be approximated by[6]

$$(2) \qquad \sum_{j=1}^{s} X_{Uncjt} = Unc_t = Lev\left(\sum_{i=1}^{f} Sfa_{it} + \sum_{k=1}^{p} Spa_{kt} - \sum_{m=1}^{d} Sdebt_{mt}\right) - \sum_{m=1}^{d} Sdebt_{mt}$$

subject to:

$$\left[Lev - \left| \frac{\sum_{m=1}^{d} Sdebt_{mt}}{\sum_{i=1}^{f} Sfa_{it} + \sum_{k=1}^{p} Spa_{kt} - \sum_{m=1}^{d} Sdebt_{mt}} \right| \right] \geq 0$$

where $j=1, \cdots, cl, \cdots, s$. Equation (2) assumes that the difference between the product of Lev times the units' equity and the units' stock of debt outstanding is a suitable measure of the value of the nonpecuniary service flow provided by unused credit reserves. This equation has many shortcomings such as treating Lev as a predetermined constant.[7] In addition,

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[5] In addition, specific services purchased by the units such as insurance can be seen to provide similar service flows, e.g., defense against misfortune, etc. Such purchases are recognized but will not be discussed further in this paper.

[6] Additional description of the notation used:

X_{Uncjt} = the jth nonpecuniary service flow provided by ownership of unused credit reserves in time period t.

Unc_t = unused credit reserves of the farm business-household unit in time period t.

Lev = The debt-to-equity ratio ceiling imposed by lenders.

$Sdebt_{mt}$ = The mth category of debt outstanding of the farm business-household unit in time period t.

d = the number of different categories of debt outstanding at the end of the year.

Spa_{kt} = the stock of the kth physical asset owned by the farm business-household units at the end of time period t.

p = the number of different species of physical assets held.

cl = the credit liquidity premium.

[7] If the data were available, one could estimate Lev with an equation such as the following:

$$Lev = L\left[\sum_{i=1}^{f} Sfa_{it}, \sum_{k=1}^{p} Spa_{kt}, Y^{e}, (i - r_{MB})^{e}\right]$$

Where: Y^{e} = the long-run expected gross farm plus personal nonfarm income of the farm business-household units.

$(i - r_{MB})^{e}$ = the long-run expected spread between the market rate of interest charged on new loans and the yield of alternative uses of loanable funds such as the rate of return on marketable government bonds (the appropriate length of maturity here would depend upon the length of the term of the loan).

This equation suggests that lenders are influenced in the long run by the owned asset structure (and presumably controlled in some cases) of the farm business-household unit, expected income of the unit, and the expected spread between the rate charged on loans and the yield of lenders' alternative uses of loanable funds.

this equation does not explicitly take account of internal credit rationing. The unit, for example, may prefer demand deposits over unused credit reserves as a source of liquidity service during periods of falling prices while the opposite may be true during periods of increasing prices. Thus, the demand for Unc_t and the nonpecuniary service flows it provides are residually explained by the farm business-household units' demand for assets and liabilities.

Liquidity and other nonpecuniary service flows provided by financial assets and unused credit reserves represent much of the cause for concern over portfolio balancing. The existence of potential trade-offs between financial assets and unused credit reserves as sources of liquidity service allows the unit to redistribute its portfolio with more emphasis on those assets yielding the greatest pecuniary rate of return in an effort to maximize its utility.

The Conceptual Model

Stocks of financial assets and unused credit reserves were shown in the previous section to be analogous to the flow of nonpecuniary services they provide. Thus, by simultaneously estimating the demand for stocks of financial *and* physical assets as well as the demand for liabilities, the units' demand for flows of nonpecuniary services provided by these assets and unused credit reserves is being alternatively approximated. The conceptual model presented in this section proposes examination of the substitution relationship among stocks of financial assets as well as the substitution relationship between these financial assets and the stock of physical assets and debt.

Tobin [24] suggests that an increase in the quantity of currency demanded will occur not only when interest rates fall and/or incomes rise but also when the capital stock of the economic unit increases, resulting in an increase in investment balances.[8] He specifies the demand function (using Penson's notation) as follows:

$$(3)\quad Sfa_{ct} = a_{co} + a_{cr}i_t + a_{cy}Y_t + a_{cw}\sum_{k=1}^{p} Spa_{kt}$$

where i is the market rate of interest. Requirements for transactions balances are assumed to depend upon the level of income, Y. Further efforts have centered on introducing other financial assets into Tobin's aggregative model and disaggregating the demand for physical assets, thus broadening the theory of liquidity preference into a more general theory of relative pecuniary rates of return on financial and physical assets. Hamburger [9, 10], for example, specifies the demand for stocks of financial assets in the household sector of the economy as

$$(4)\quad Sfa_{it}^{*} = a_{io} + \sum_{j=1}^{n} a_{ij}r_{jt} + a_{iy}Y_t + a_{iw}W_t$$

where the asterisk denotes desired stocks, r is a vector of pecuniary rates of return on financial assets, and W represents the financial wealth of the households.[9] In a companion study, Hamburger [11, p. 1132] states, "... the desired aggregate stock of any given physical asset ... [is a] ... linear function of Y, aggregate income valued at constant prices; r, a vector of yields on financial assets and liabilities; and P, the price of the asset relative to the price of all other goods and services purchased by consumers." The technique used by Hamburger to examine the substitution relationship between physical and financial assets is rather unique. He [11, p. 1140] suggests, however, "As a general rule, it is the stock of liquid assets rather than their yields which is used as an independent variable in the durables equations."

[8] Tobin [25] defines investment balances as those that survive the income period. He suggests that these balances can be found in any number of forms, including money if the capital value risk is high in alternative assets. With financial intermediaries and governments offering a variety of claims which are liquid *and* yield a return to the unit, it would appear that the only rational motive for owning money is requirements for transactions balances. There are at least two possible exceptions to such a conclusion. First, demand deposits may be found in investment balances due to uncompleted shifts between demand deposits and claims as a result of unexpected residual funds [18] or between claims as a result of a price change [23]. Second, Smith [21, p. 221] suggests that the various forms of saving are not a completely adequate source of liquidity service since they either require varying lengths of time to convert to money as in the case of time and savings deposits or involve conversion costs as in the case of marketable securities; therefore, "... on balance, it is commonly desirable to hold at least a portion of the assets needed to satisfy the precautionary motive in the form of cash balances." Passbook savings accounts where interest is computed daily and deposits are withdrawable upon demand would appear to come the closest to satisfying Smith's criterion. These deposits, however, normally provide a lower pecuniary rate of return than other forms of time deposits available to the unit.

[9] Hamburger's definition of wealth can be questioned on at least two counts: (1) the dependent variable is included in the definition of W, and (2) the specification fails to take account of the substitution relationship between physical and financial assets (Hamburger recognizes this limitation on [10, p. 101]).

Neither specification in and of itself, however, takes account of the simultaneous substitution relationship suggested by the theory of portfolio balance. Hammer [12] states, "An expanded portfolio balance model with supporting statistical evidence, in which the desired stock of various critical assets and the flows to which they give rise are simultaneously determined, appears to provide the most promising approach to the framework desired." Broadening the coverage to include liabilities, the following abbreviated system of simultaneous equations is offered as a first approximation of the desired portfolio balance in the farm sector:[10]

$$Sfa_{it}^* = a_{io} + \sum_{j=1}^{n} a_{ij} r_{jt} + a_{iy} Y_t$$

$$(5) \qquad + a_{iwp} \sum_{k=1}^{p} Spa_{kt}^*$$

$$(i = 1, \cdots, c, dd, td, \cdots, f;$$
$$j = 1, \cdots, DD, TD, MB, EQ, \cdots, n).$$

$$Spa_{kt}^* = a_{ko} + \sum_{j=1}^{n} a_{kj}(r_j - i_m)_t$$

$$(6) \qquad + a_{kwf} \sum_{i=1}^{f} Sfa_{it}^*$$

$$(k = 1, \cdots, \sum nre, \cdots, \sum re, p;$$
$$j = 1, \cdots, NRE, \cdots, RE, n).$$

$$(7) \quad Sdebt_{mt}^* = a_{mo} + a_{mr} i_{mt} + a_{mwp} \sum_{k=1}^{p} Spa_{kt}^*$$
$$(m = 1, \cdots, nre, \cdots, re, d).$$

The demand for financial assets is specified in equation (5) to be a linear function of r, a vector of pecuniary rates of return on marketable and nonmarketable financial assets; Y, gross farm plus personal nonfarm income (gross flow of income to the unit); and $\sum Spa_k^*$, the desired stock of physical assets. Equation (6) specifies the demand for desired stocks of physical assets to be a linear function of $(r_j - i_m)$, a vector of the spreads between the pecuniary rates of return on real estate and non-real estate assets and the cost of borrowed funds to the units expressed in real terms; and $\sum Sfa_i$, the stock of financial assets.[11] Equations (5) and (6) allow for the simultaneous estimation of the substitution relationship between the demand for desired stocks of financial and physical assets. Inventories of crops and livestock are aggregated with other non-real estate assets rather than with financial assets in the model. These inventories may provide nonpecuniary service flows much like those provided by financial assets and unused credit reserves, if they are readily marketable and their value does not fluctuate greatly.

Equation (7) specifies the demand for desired stocks of debt outstanding in the year-end portfolio as a linear function of i_m, the rate of interest, and $\sum Spa_k$, the stock of physical assets at the end of the period.[12] The stock of

[10] Additional description of the notation used:

r_{jt} = a vector of own and alternative pecuniary rates of return on assets providing like nonpecuniary service flows in time period t.

DD = the service charge rate on demand deposits at insured commercial banks.

TD = the rate of return on time and savings deposits at insured commercial banks.

MB = the rate of return on marketable U.S. Government long-term bonds.

EQ = the rate of return on equities (Moody's dividend yield on 125 selected common stocks).

i_m = the relevant market rate of interest (real estate or non-real estate) on loans made to the farm business-household units.

Σnre = the aggregate of non-real estate assets held by units.

Σre = the aggregate of real estate assets held by units.

Y = gross farm plus personal nonfarm income of the units.

NRE = the rate of return on non-real estate assets in the farm sector.

RE = the rate of return on real estate assets in the farm sector.

nre = non-real estate debt outstanding.

re = real estate debt outstanding.

$*$ = denotes desired stocks of assets and liabilities.

[11] The rate of return on assets, defined as the nominal returns per unit divided by the price of the asset, rather than profits, was used in equation (6) to determine the effect of increased returns on investment. Klein and Goldberger [13] chose the alternative of including current net income, lagging the current liquid asset variable one period to avoid the problem of profits being included in current liquid assets. By doing this however, they also avoided the simultaneity of the substitution relationship between financial and physical assets.

In addition, it is assumed in this study that the demand for physical assets is largely independent of supply, i.e., that the supply of real estate assets is highly inelastic while the supply of production items is highly elastic. An expanded conceptual model should attempt to relax such an assumption.

[12] The stock of debt outstanding at the end of the year is also simultaneously determined by such supply-related factors as (1) the rate of interest, (2) the level of excess reserves at country commercial banks, (3) the spread between the rate of interest charged and the rate of return on alternative investments available to the lender such as the various forms of marketable U.S. Government securities, and (4) the Federal Reserve discount rate. The extent to

physical assets is included in equation (7) to determine the substitution relationship between the demand for these assets and the stock of debt outstanding in the farm business-household units' portfolio. As an alternative to equation (7), one could substitute those regressors that determine the demand for physical assets [see equation (6)] directly into equation (7).[13]

Speed of adjustment

For some portfolio components, particularly demand deposits and currency, the length of time required to adjust actual stocks of desired levels is relatively short. For example, Maddala and Vogel [16] show that the corporate business sector would close approximately 89 percent of an initial disequilibrium gap between desired and actual stocks of demand deposits and currency within the year the permanent economic stimulus was received. Thus, one could approximate desired amounts by merely observing actual balances. For those assets involving high transactions costs, construction lags, etc., however, the length of the adjustment period has been shown to be much longer [1].

Equations (8) and (9), expressed in general terms for illustrative purposes, provide a model for describing the adjustment process of actual stocks to desired levels:

$$S_{it} - S_{it-1} = (I_{it} - D_{it}) = \phi_i(S_{it}^* - S_{it-1}) \qquad 0 \leq \phi_i \leq 1 \tag{8}$$

giving the following demand for actual stocks:

$$S_{it} = \phi_i S_{it}^* + (1 - \phi_i)S_{it-1} \tag{9}$$

where S_{it}^* is defined in specific terms in equations (5), (6), and (7). When the portfolio is balanced, the adjustment coefficients (ϕ_i) will be equal to one, causing the lagged regressand in equation (9) to fall out and desired stocks and actual stocks to be equal. If the period of adjustment for these stocks is considerable (where it has been shown to be in other sectors), actual stocks can no longer serve as approximations of desired levels. This means, of course, that a portfolio balance model as such no longer exists but rather a modified model that describes the effect of past completed plans on stocks of financial and physical assets held at the end of the period [12, p. 106]. Facing a similar situation, Hammer states, "A primary conclusion of the present study is that it is indeed useful to view the demand for capital, at least in the aggregate, through the perspectives provided by portfolio balance theory."

The Statistical Model

The demand for commercial bank deposits, the primary focus of this study, is expressed in this section as functions of r, a vector of pecuniary rates of return on financial assets; Y, gross farm plus personal nonfarm income valued at constant prices; and $\sum Spa_k$, the stock of physical assets valued in real terms.[14] Rather than assume that actual stocks of these assets are a good approximation of desired stocks, the empirical model tested will be of a dynamic nature. The lagged regressand will be included among the regressors to determine the length of the adjustment period. Letting Sfa_i represent the real value of end-of-the-year stocks of commercial bank deposits, then

$$\begin{aligned} Sfa_{it} = {} & a_{io} + \sum_{j=1}^{n} a_{ij} r_{jt} + a_{iy} Y_t \\ & + a_{iw} \sum_{k=1}^{p} Spa_{kt} + a_{ik} Sfa_{it-1} \\ & + u_{it} \end{aligned} \tag{10}$$

where $i = dd$ and td, $j = DD$, TD, MB, and EQ, and u is the random error term.

The pecuniary rate of return on demand deposits varies inversely with the service charge rate on demand deposits at commercial banks. That is, the rate of return on demand deposits is *increased* when the service charge rate on demand deposits at commercial banks *decreases*. Since r_{DD} is represented by the service charge rate, the corresponding a_{ddDD} coefficient in the demand deposits equation is expected to be negative. An increase in the jth pecuniary rate of return ($j \neq DD$) in the demand deposits equation is expected to cause the utility maximizing unit to substitute this financial asset for de-

which the current amount of funds supplied ($\Delta\Sigma Sdebt_{mt}$) in time period t is less than unused credit reserves of the units (Unc_t) reflects a joint decision on the part of lenders *and* farm business-household units to ration credit further in any one year.

[13] Choice of this alternative would not alter the list of predetermined variables included in the first stage regression of the two stage least squares regression technique used in this study.

[14] It is assumed in this study that demand deposits and time and savings deposits can be purchased at commercial banks in unlimited amounts at their announced rates. It is further assumed that these rates are determined exclusive of the level of i_{mt}.

mand deposits in the portfolio if the two assets are indeed substitutes. Thus, the expected signs on a_{ddTD}, a_{ddMB}, and a_{ddEQ} coefficients are negative if the assets are substitutes and positive if the assets are complements. The sign on the a_{tdTD} coefficient in the time deposits equation is expected to be positive. The expected sign on a_{tdDD} is positive while the expected signs on a_{tdMB} and a_{tdEQ} coefficients are negative if these three assets are substitutes for time and savings deposits in the units' portfolio. The a_{dd_y} coefficient on the income regressor in the demand deposit equation is expected to be positive and the a_{td_y} coefficient on the income regressor in the time and savings deposits equation is expected to be negative if requirements for transactions balances are an important determinant of the demand for demand deposits [10, p. 106]. The a_{dd_w} and a_{td_w} coefficients in the two equations are expected to be positive, their size depending upon the relative importance of these assets as sources of liquidity service relative to that provided by unused credit reserves.

The two stage least squares regression technique was used in this study to estimate the coefficients for the regressors included in equation (10). This procedure was used to take account of the simultaneity in the system of structural equations presented in the previous section. A total of 16 current and lagged predetermined regressors suggested by the conceptual model were employed in the first stage regression.[15]

Data

The time series data employed in this study are comprised of annual observations covering the 1948–1970 period. Most of these data are readily available in published form while others require additional computation.[16] Those regressors requiring additional computation will be reviewed below.

The service charge rate on demand deposits was approximated by dividing the total service charges on demand deposits reported by insured commercial banks to the Federal Deposit Insurance Corporation (FDIC) by the annual average demand deposit balance reported. The rate of return on time and savings deposits was approximated by dividing the total interest paid on time and savings deposits reported by insured commercial banks to the FDIC by the annual average time and savings deposit balances reported.

Mention was made earlier that the stock of currency cannot be empirically examined due to the manner in which the time series is estimated. The stock of currency reported in the *Balance Sheet for the Farming Sector* (BSFS) [27] is estimated as a constant 46 percent of demand deposits owned by farm business-household units at commercial banks. In addition, estimates of time deposits and savings deposits at commercial banks are made jointly even though they are published in the BSFS as "time deposits." Separate demand equations for these financial assets, therefore, cannot be empirically examined.[17]

All variables valued in nominal units in this study have been deflated by the 1958 implicit GNP deflator published by the Department of Commerce [26].[18] These variables include the

[15] These variables are as follows: r_{DDt}, r_{TDt}, r_{MBt}, r_{EQt}, Y_t, Sfa_{ddt-1}, Sfa_{tdt-1}, r_{NREt}, r_{REt}, Spa_{nret-1}, Spa_{ret-1}, r_{TBt}, XRV_t, r_{DISCt}, $Sdebt_{nret-1}$, and $Sdebt_{ret-1}$. Those factors influencing the demand for and supply of debt have been explicitly taken into account in the statistical model, thus explaining why i_{nt} is not included among the list of predetermined regressors. Excess reserves at country commercial banks are represented by XRV_t, r_{DISCt} denotes the discount rate, and r_{TBt} represents the 90-day Treasury bill rate. If one increased this number by further disaggregating the various classes of assets and debt, the number of predetermined regressors may become as large or larger than the sample size so that a meaningful first stage regression would not be possible. Kloek and Mennes [14] and Mitchell [19] suggest several simultaneous estimators designed to alleviate this problem by allowing the user to choose a limited number of predetermined regressors for the first stage regression.

[16] A complete listing of the time series data used in this study is available from the author upon request. For additional information on the definition of the farm sector used in this study, see Penson, Lins, and Irwin [20, p. 2].

[17] A data limitation faced at the onset of this study is a lack of quarterly or semi-annual observations of the stock of demand deposits and time and savings deposits in the farm sector. Such a limitation potentially hampers the analysis of requirements for transactions balances as a determinant of demand. One would not expect, in the aggregate, that the transactions motive would be as important in determining the desired year-end stock of demand deposits as it would have been if quarterly or semi-annual stocks were being examined, due to the biologic nature of many of the forms of production in the farm sector and the corresponding seasonal flows of income and expenditures.

[18] One apparently cannot accurately separate price changes resulting from inflationary trends in available price deflators for farm sector capital expenditures from price changes attributable to changes in productive capacity. An alternative suggested in the literature is to use the implicit GNP price deflator, the broadest based price index available. By doing so, Hammer [12, p. 61] states that we have ". . . abandoned the attempt to measure changes in the physical volume of operations." Instead, we are measuring the real stock of assets defined in terms of dollars of constant purchasing power.

Table 1. Selected simultaneous equations estimates of the structural demand equations for demand deposits and time and savings deposits

Regressand	Intercept	r_{DD}	r_{TD}	r_{MB}	r_{EQ}	Y	ΣSpa_t	Lagged dependent
Section I:								
I.1 Demand deposits	1.3027	−1.6043	.1625	−.0987	−.0316	−.0076	.0051	.2576
	***	***	**	***	**		*	*
	(.2747)	(.4009)	(.0681)	(.0258)	(.0118)	(.0141)	(.0035)	(.1535)
I.2 Time and savings deposits	.4507	−1.2267	.2367	−.0906	−.0077	−.0266	.0092	.5787
	***	***	***	***		**	***	***
	(.1540)	(.4028)	(.0655)	(.0229)	(.0100)	(.0130)	(.0041)	(.1553)
Section II:								
II.1 Demand deposits	1.2622	−1.5321	.1479	−.0946	−.0334		.0039	.2645
	***	***	**	***	***		*	**
	(.2578)	(.3687)	(.0610)	(.0241)	(.0110)		(.0027)	(.1493)
II.2 Time and savings deposits	.3723	−1.0648	.2172	−.0842		−.0290	.0098	.5988
	***	***	***	***		**	***	***
	(.1137)	(.3386)	(.0595)	(.0211)		(.0125)	(.0040)	(.1509)

* = coefficient statistically different from zero at the 10 percent level.
** = coefficient statistically different from zero at the 5 percent level.
*** = coefficient statistically different from zero at the 1 percent level.
Figures in parentheses are standard errors.

stocks of assets and flows of income specified in equation (10). The various rates of return examined already reflect their true yield in percentage terms [12, pp. 28–29]. In addition, these stocks of assets and flows of income have been adjusted for changes in the number of farm business-household units over the time period studied.

Results

The results from the simultaneous estimation of the regressor coefficients included in equation (10) are reported in Table 1. Section I (Table 1) presents the estimates of the regressor coefficients for the demand deposit and time and savings deposit equations as specified in equation (10). Section II (Table 1) presents the estimates of these coefficients after all regressors whose coefficients were not significantly different from zero at the 10 percent probability level or less have been eliminated.

Although some of the regressors are highly intercorrelated due to an upward trend element, the corresponding regressor coefficients are, for the most part, significantly different from zero at the 10 percent level or less. The signs on the significant coefficients are also consistent with the basic theory underlying the portfolio balance approach. These facts, coupled with additional tests and comparisons with studies made for other sectors of the economy, indicate that the results presented are plausible.

Speed of adjustment

The a_{dd1} coefficient on the lagged dependent variable in equation II.1 has the expected sign and is significantly different from zero at the 5 percent level. The adjustment coefficient ($\phi_{dd}=1-a_{dd1}$) of .735 implies that approximately 74 percent of an initial disequilibrium gap between actual and desired stocks of demand deposits is closed within the first year, assuming no further disturbances are received. As reported earlier, Maddala and Vogel [16] estimated that the corporate business sector would close 89 percent of an initial disequilibrium gap in the demand for demand deposits and currency within the year the permanent economic stimulus is received. Hamburger, however, estimates that the household sector would close 61 percent of an initial gap in the demand for demand deposits and currency within the first year. Thus, it appears that the speed of adjustment toward long-run equilibrium holdings of demand deposits in the farm sector may be somewhat slower than that estimated for the corporate business sector while somewhat faster than that estimated for the household sector.

Equation II.2 shows that the a_{td1} coefficient on the lagged regressand in the time and savings deposit equation is significantly different from zero at the 1 percent level. An adjustment coefficient of .401 implies that it would take approximately three years before 79 percent of an

initial disequilibrium gap between actual and desired stocks of time and savings deposits is closed, assuming no further disturbances are received. By way of comparison, Hamburger shows that approximately 52 percent of an initial disequilibrium gap in the demand for time and savings deposits would be closed in the first year and that 76 percent of this gap would be closed within the first two years. Thus, the speed of response toward long-run equilibrium holdings of time and savings deposits is estimated to be substantially slower in portfolios of farm business-household units than that for household units in general.

Table 2. Long-run equilibrium elasticities for the rate of return regressors in the demand deposit and time and savings deposit equations (II.1 and II.2)

Regressands	Regressors			
	r_{DD}	r_{TD}	r_{MB}	r_{EQ}
Demand deposits	−.490[a]	.334	−.318	−.129
Time and savings deposits	−.698[a]	.419	−.386	—[b]

[a] Price rather than yield elasticity.
[b] Coefficient for this regressor was not significantly different from zero at the 10 percent level.

Financial asset substitution

The long-run equilibrium elasticities for the various rates of return on marketable and nonmarketable financial assets are presented in Table 2 to facilitate discussion of the substitution relationships among these financial assets. These elasticities, computed at their means, correspond to equations II.1 and II.2 in Table 1.

The own price elasticity of demand for demand deposits of −.490 indicates that the units' demand is inelastic in long-run equilibrium. Feige [7] reports an own price elasticity of demand for demand deposits of −.310 for individuals (including businesses) throughout the economy. The own yield elasticity of demand for time and savings deposits at commercial banks is shown in long-run equilibrium to be an inelastic .419. This result is somewhat lower than the elasticity of .663 reported by Hamburger for household units in general but is close to the elasticity of .490 reported by Feige for individuals including businesses.

The cross elasticity coefficients for r_{DD} and r_{TD} at commercial banks indicate that demand deposits and time and savings deposits are complements in the units' portfolio at the end of the year. The cross yield elasticity for r_{TD} in the demand deposit equation is .334. While this complementary result is at odds with results published for other sectors of the economy, the result is not totally unexpected for the farm sector. The hypothesis was advanced earlier that requirements for investment balances would dominate requirements for transactions balances as determinants of the year-end stock of demand deposits in the farm sector due to the unique seasonal nature of many income and expenditure flows (see footnote 17). Demand deposits are thought to be required in investment balances since time and savings deposits and other financial claims are not a completely adequate source of liquidity service (see footnote 8). In the present case, time and savings deposits require varying degrees of time to convert to demand deposits, particularly those forms of time deposits providing the highest pecuniary rates of return. Smith [21, p. 221] suggests, therefore, "On balance, it is commonly desirable to hold at least a portion of the assets needed to satisfy the precautionary motive in the form of cash balances." Thus, if r_{TD} increases, the units will increase their stocks of time and savings deposits *and* demand deposits if other things remain equal, thereby maintaining a certain degree of perfect disposal liquidity in holdings of commercial bank deposits. Looking at the other side of this relationship, the cross price elasticity for r_{DD} in the time and savings deposit equation is −.698. Thus, an increase in r_{DD}, other things remaining equal, would cause units to decrease their stock of demand deposits *and* time and savings deposits at commercial banks. These results appear to imply that farm business-household units would take a portion of their investment needs elsewhere if the profitability of total investment in commercial bank deposits decreases. These conclusions, of course, are based on estimates of aggregate year-end farm business-household unit behavior. As such, these estimates may or may not be applicable to any one unit at the end of the year or to units in general at other times during the year.

The cross elasticities for r_{MB} and r_{EQ} in the demand deposits equation show that both forms of marketable securities are substitutes for demand deposits in the units' year-end portfolio. This result, coupled with the results pre-

sented for r_{TD}, implies that farm business-household units distinguish between time and conversion costs when allocating demand deposits for disposal liquidity purposes. Marketable bonds are also shown to be a substitute for time and savings deposits held by units at the end of the year. The coefficient on r_{BQ}, however, was not significantly different from zero in the time and savings deposit equation. These results are similar to those reached by Hamburger [9, 10] for household units in general. There is one essential difference, however. Hamburger [9] shows that the cross elasticities for r_{MB} and r_{BQ} in the demand deposit and currency equation are approximately equal in the household sector. It is the finding of the present study that the cross yield elasticity for r_{MB} in the demand deposit equation is greater than that for r_{BQ}. This difference may, in part, be the result of units in the farm sector taking a stronger account of the potentially greater price changes associated with marketable equity instruments.

Requirements for transactions balances

The a_{ddy} coefficient for Y in the demand deposit equation is not significantly different from zero at the 10 percent level. In addition, the coefficient has the opposite sign from what one would expect if requirements for transactions balances were important. Part of the reason for these results may be that requirements for transactions balances to satisfy expenditure claims are swamped by investment balances requirements as determinants of the year-end stock of demand deposits as hypothesized earlier. The negative sign on the a_{ddy} coefficient is consistent with this reasoning. Requirements for demand deposits in investment balances may decrease as Y increases based upon an "expectations effect." If the farm business-household units believe that Y will be more than enough to cover anticipated expenditure flows, they may feel less of a need for those nonpecuniary services provided by demand deposits and other financial assets. Units seeking to maximize utility may desire to redistribute their portfolio of assets and liabilities in favor of those assets providing greater pecuniary services. Acquisition of these assets would undoubtedly increase the flow of credit liquidity services to the unit (see footnote 7), thereby partially offsetting the losses in disposal liquidity services. Thus, there are several factors that influence the relationship between Y and the desired year-end stock of demand deposits. The interaction between these factors may, in part, account for the statistical results obtained. Disposable farm plus disposable nonfarm income of the farm business-household units was tested as an alternative definition of Y with little or no difference in the results observed. It was thought that the latter definition of Y may be more applicable since requirements for business transactions balances do not appear to be relatively important in year-end portfolios.

The a_{tdy} coefficient for the Y regressor in the time and savings deposit equation is significantly different from zero at the 5 percent level and has the expected sign. The negative sign on this coefficient is consistent with the "expectation effect" and transactions balances hypotheses advanced above. An income elasticity coefficient of .432 implies that a 10 percent increase in Y would prompt farm business-household units to decrease their time and savings deposits by 4.3 percent, other things equal.

Physical asset substitution

The a_{ddw} coefficient for the stock of physical assets regressor in the demand deposit equation is significantly different from zero at the 10 percent level. The computed long-run equilibrium elasticity of .168 implies that a 1 percent increase in the stock of physical assets would bring about a .168 percent increase in demand deposits in year-end portfolios. Applying these percentages to the stocks of these assets reported in the BSFS on January 1, 1970, it can be seen that a 1 percent increase in the stock of physical assets would amount to $2.9 billion, while a .168 percent increase in the stock of demand deposits amounts to $7.4 million. Thus, the increase in the stock of physical assets would be approximately 392 times greater than the increase in demand deposits in year-end portfolios of farm business-household units.

The a_{tdw} coefficient for the stock of physical assets regressor was significantly different from zero at the 1 percent level in the time and savings deposit equation. The computed long-run equilibrium elasticity of .576 implies that a 1 percent increase in the stock of physical assets would cause units in the aggregate to increase their stock of time and savings deposits by approximately .6 percent at the end of the year. Applying these percentages to the stocks of assets in the sector on January 1, 1971, again, increases in the stock of physical assets would be approximately 92 times greater than the corres-

ponding year-end increase in the stock of time and savings deposits.

These results suggest that demand deposits are inferior to time and savings deposits in the units' year-end portfolio in the sense that increases in the stock of physical assets reduce the percentage that demand deposits are of total financial assets more so than for time and savings deposits. Much of the reason for this relationship can undoubtedly be attributed to the positive pecuniary services provided by time and savings deposits in addition to the usual nonpecuniary services provided by commercial bank deposits.

Policy Implications

The results presented above have some rather important policy implications for monetary authorities concerned with the impact their actions have on year-end holdings of commercial bank deposits in the farm sector. For example, actions taken to raise the maximum r_{TD} at commercial banks may result in a greater increase in the rate of loan expansion at banks where deposits held by the farm sector account for the majority of total deposits than for commercial banks in general. If the farm sector-oriented commercial banks respond by increasing r_{TD}, farm business-household units would increase their ownership of time and savings deposits *and* demand deposits, other things equal.

Actions taken to increase reserve requirements on demand deposits for the purpose of lowering bank net free reserves may also have the opposite effect anticipated *if* these farm sector-oriented commercial banks respond by increasing r_{TD} to attract additional time and savings deposits as a basis for further loan expansion. A 1 percent increase in r_{TD} was shown in this study not only to result in an increase in the quantity of time and savings deposits demanded at the end of the year of .4 percent but also to cause a .3 percent increase in the demand for demand deposits, other things equal. Thus, the fractional reserve requirement on demand deposits may well be applied to a *larger* demand deposit balance at the end of the year in those banks where deposits held by the farm sector are predominant. This would allow for higher rates of loan expansion and lower interest rates *than otherwise anticipated*. If these banks had instead increased r_{DD} to offset losses in the "profitability" of demand deposits in *their* year-end portfolio, the results indicate that farm business-household units' ownership of commercial bank deposits would *decline*.

Open market purchases and sales of government securities would appear to be an effective tool for indirectly monitoring year-end loan expansion at farm sector-oriented commercial banks. For example, even if the commercial banks do not alter *their* holdings of marketable government securities, their deposit base may still change since marketable government bonds are shown to be a substitute for demand deposits and time and savings deposits in the units' portfolio.

References

[1] ALMON, SHIRLEY, "The Distributed Lag Between Capital Appropriations and Expenditures," *Econometrica* 33:178–196, Jan. 1965.

[2] BAKER, C. B., "Credit in the Production Organization of the Firm," *Am. J. Agr. Econ.* 50:507–520, Aug. 1968.

[3] BRONFENBRENNER, MARTIN, AND THOMAS MAYER, "Liquidity Functions in the American Economy," *Econometrica* 28:810–834, Oct. 1960.

[4] CHOW, G., "On the Long-Run and Short-Run Demand for Money," *J. Polit. Econ.* 74:111–131, April 1966.

[5] DAVIDSON, PAUL, "A Keynesian View of the Relationship Between Accumulation, Money and the Money Wage-Rate," *Econ. J.* 79:300–323, June 1969.

[6] DURBIN, J., "Testing for Serial Correlation in Least-Squares Regression When Some of the Regressors Are Lagged Dependent Variables," *Econometrica* 38:410–421, May 1970.

[7] FEIGE, E., *The Demand for Liquid Assets: A Temporal Cross-Section Analysis*, Englewood Cliffs, N.J., Prentice-Hall, Inc., 1964.

[8] FRIEDMAN, MILTON, AND DAVID MEISELMAN, "The Relative Stability of Monetary Velocity and the Investment Multiplier in the United States, 1897–1958," in *Stabilization Policies*, eds., E. Cary Brown, Robert M. Solow, Albert Ando, *et al.*, Englewood Cliffs, N.J., Prentice-Hall, Inc., 1963.

[9] HAMBURGER, MICHAEL J., "The Demand for Money by Households, Money Substitutes, and Monetary Policy," *J. Polit. Econ.* 74:600–623, Dec. 1966.

[10] ———, "Household Demand for Financial Assets," *Econometrica* 36:97–118, Jan. 1968.

[11] ———, "Interest Rates and the Demand for Consumer Durable Goods," *Am. Econ. Rev.* 57:1131–1153, Dec. 1967.

[12] HAMMER, FREDERICK S., *The Demand for Physical Capital: Application of a Wealth Model*, Englewood Cliffs, N.J., Prentice-Hall, Inc., 1964.

[13] KLEIN, L. R., AND A. S. GOLDBERGER, *An Econometric Model of the United States, 1929–1952*, Amsterdam, North-Holland Publishing Company, 1955.

[14] KLOEK, T., AND L. B. M. MENNES, "Simultaneous Equations Estimation Based on Principal Components of Predetermined Variables," *Econometrica* 28:45–61, Jan. 1960.

[15] LATANÉ, HENRY ALLEN, "Cash Balances and the

Interest Rate—A Pragmatic Approach," *Rev. Econ. & Stat.* 36:456–460, Nov. 1954.

[16] MADDALA, G. S., AND ROBERT C. VOGEL, "Estimating Lagged Relationships in Corporate Demand for Liquid Assets," *Rev. Econ. & Stat.* 51:53–61, Feb. 1969.

[17] MCMAHON, W. W., "Dynamic Interdependence in Consumer Stocks, Tastes, and Choices," unpublished working paper, Department of Economics, University of Illinois 1969.

[18] MEYER, JOHN R., AND EDWIN KUH, *The Investment Decision. An Empirical Study*, Cambridge, Harvard University Press, 1957.

[19] MITCHELL, B., "Estimation of Large Econometric Models by Principal Component and Instrumental Variable Methods," *Rev. Econ. & Stat.* 53:140–146, May 1971.

[20] PENSON, JOHN B., JR., DAVID A. LINS, AND GEORGE D. IRWIN, "Flow-of-Funds Social Accounts for the Farm Sector," *Am. J. Agr. Econ.* 53:1–7, Feb. 1971.

[21] SMITH, W., *Macroeconomics*, Homewood, Ill., Richard D. Irwin Publishing Company, Inc., 1970.

[22] STEDRY, ANDREW C., "A Note on Interest Rates and the Demand for Money," *Rev. Econ. & Stat.* 41:303–307, Aug. 1959.

[23] TEIGEN, RONALD L., "Demand and Supply Functions for Money in the United States: Some Structural Estimates," *Econometrica* 32:476–509, Oct. 1964.

[24] TOBIN, JAMES, "A Dynamic Aggregative Model," *J. Polit. Econ.* 63:103–115, April 1955.

[25] ———, "Liquidity Preference as Behavior Towards Risk," *Rev. Econ. Stud.* 25:65–86, Feb. 1958.

[26] U.S. Department of Commerce, Office of Business Economics, *Survey of Current Business*, Vol. 51, Aug. 1971.

[27] U.S. Department of Agriculture, Economic Research Service, *The Balance Sheet for the Farming Sector*, Bull. 350, Jan. 1971.

Market Solutions to Externality Problems: Theory and Practice*

ALAN RANDALL

The concept of market solution to externality problems has received the favorable attention of many economic theorists. Yet, policy practitioners and the general public seem less enthusiastic. Theoretical studies and available empirical work have effectively demolished Coase's doctrine of the allocative neutrality of liability rules. In reality, a full liability law will result in a greater degree of abatement of external diseconomies than will zero or intermediate liability laws. It is suggested that market solutions can be seriously considered in a world with pervasive externalities only if something approaching a full liability rule is established. Even then, excessive transactions costs may limit the success of market solutions.

AGRICULTURAL economists are directly and immediately concerned with externalities in agricultural settings, such as the problems of pesticide residues and animal waste disposal. But their concern with externalities is much wider than these. All forms of pollution from industrial and municipal sources in both urban and rural areas, externalities associated with consumption activities such as driving automobiles for pleasure, the whole range of externalities arising from land zoning, subdivision, and provision of utilities and community services, and so on, are of interest to the agricultural economist because they influence the geographic distribution and the urban-suburban-rural mix of the population.

An externality is said to exist wherever the utility of one or more individuals is dependent upon, among other things, one or more activities which are under the control of someone else. Buchanan and Stubblebine [2] have defined a Pareto-relevant externality as one which may be modified in such a way as to make the externally affected party better off without making the acting party worse off. A Pareto-relevant externality is characterized by the existence of potential gains from trade between the affected and acting parties. In what follows, the term externality may be taken to mean Pareto-relevant externality. An external diseconomy is an externality in which the affected party is made worse off by the activities of the acting party.

Many of society's environmental quality problems, particularly those types of problems which are referred to in the popular literature as spillover effects, are the result of external diseconomies. Improvement of environmental quality requires a modification of the behavior of acting parties who produce these external diseconomies.[1]

The Theory

Economic theory is based on the premise that if one wishes to modify the behavior of an economic unit, one must modify the incentives facing that unit so that the preferred behavior becomes more appealing to it (i.e., more pleasant, more profitable, or both). Economic literature on environmental quality externalities considers three broad classes of methods of solution of environmental quality problems, each designed to make the creation of Pareto-relevant externalities less profitable to acting parties. They are (1) market solutions, following establishment of a liability rule to serve as a starting point for negotiations; (2) systems of per unit taxes, charges, fines, or subsidies; and (3) systems of standards, enforced by the threat of fines or jail sentences. While (1) relies on private negotiation and (2) and (3) on government intervention, the three classes represent a clear progression from more to less reliance on market forces to determine the equilibrium output of externality.

The logical underpinnings of the suggestion that the market may be relied upon to achieve solutions to externality problems are presented by its supporters as follows: A Pareto-relevant externality is, by definition, characterized by the existence of potential gains from trade be-

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ALAN RANDALL *is assistant professor of agricultural economics at New Mexico State University.*

[1] Mishan [11] and an anonymous reviewer suggest that the adverse effects of a degraded environment on people may in some cases be minimized by evasive action taken by the affected party. However, this type of solution would not strictly improve environmental quality.

tween the acting and affected parties. Surely, then, self-interest can be relied upon to ensure the realization of these potential gains through exchange between the involved parties. As always, efficient exchange requires precisely defined and rigidly enforced property rights. In the case of external diseconomies, these property rights include some specification of the laws of liability for damages associated with the diseconomy. If liability rules are specified in a particular manner—allowing a specified amount of externality to be created with impunity and that amount to be exceeded only if the affected party is willing to agree—they serve as the starting point for negotiations to realize the potential gains from trade. The two extreme examples of such liability rules are the zero liability rule, L^z, and the full liability rule, L^f; an infinite number of intermediate rules could be conceived. L^z specifies that external diseconomies in any amount may be created with impunity; under such a rule, the affected party would have an incentive to offer a bribe to induce the acting party to reduce his output of external diseconomy. L^f specifies that absolutely no externality may be created without the consent of the affected party; under such a rule, the acting party would have an incentive to offer compensation to induce the affected party to accept a positive amount of externality.

Coase [5] perceived that regardless of which liability rule is in operation one or another party has an incentive to modify a Pareto-relevant externality. Given perfect competition and zero transactions costs,[2] negotiations will continue until all gains from trade have been exhausted. Coase argued that all gains from trade will be exhausted at the same Pareto-efficient outcome, regardless of which liability rule is in operation. In other words, the market solution to a particular externality problem is allocatively neutral with respect to the assignment of liability. Of course, the specification of liability influences the final distribution of income at the completion of the exchange, since an L^z rule would result in the affected party making payments to the acting party and an L^f rule would result in the opposite flow of payments.

It is understandable that such an approach to externalities would be attractive to academic economists. It relies upon the market to establish the price of an externality. All the society has to do is to establish a liability rule, and it does not matter too much what that rule is since any rule will result in the same Pareto-efficient equilibrium solution. If society is concerned with income distribution, it may either attempt to choose a liability rule which will lead to a satisfactory distribution of income or use any other income redistribution method to attempt to restore a situation of equity.

Of the three broad groups of methods of solving externality problems listed above, it is noticeable that academic economists usually prefer market solutions or systems of fines, charges, taxes, or subsidies. There is a group of academic economists who remain fervent supporters of the market solution method. However, politicians, administrators, and the general public seem to have more faith in systems of standards. This divergence of opinion between academic economists on the one hand and the public and its representatives on the other motivated the preparation of this paper, which focuses on market solutions in theory and practice and offers some speculations on their future.

The Coasian analysis of externality was rapidly enshrined in the economic literature. Whereas Coase's analysis concentrated entirely on the case where both the acting and the affected parties were single firms engaged in production, Davis and Whinston [7] in 1965 extended the analysis to the case where both parties were single consumers. Their results duplicated those of Coase in all respects, including the finding of allocative neutrality of liability rules. Calabresi [4] spoke for the proponents of market solutions in 1968: all externalities can be internalized and all misallocations can be remedied by the market except to the extent that transactions cost money.[3]

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[2] It is worthwhile to define transactions costs carefully, since they play an important part in the analysis to follow. Transactions costs are the costs of making and enforcing decisions. Included are the costs of obtaining information, establishing one's bargaining position, bargaining and arriving at a group decision, and enforcing the decision made. Any method of modifying externalities will involve some transactions costs. The size of the transactions costs and the type of transactions services used are likely to vary with the use of different types of solution methods and with the actual solution obtained. Transactions costs may be so large that they become a major factor in the selection of an efficient method of solution of any particular externality problem.

[3] This line of reasoning culminated in Demsetz's argument [8] that where a market for an external diseconomy does not exist it should not exist, since the benefits from

Beginning in 1966, the Coasian analysis came under attack from at least two quarters. One group claimed that Coase's assumptions were so far removed from the real world that his analysis was irrelevant for prescriptive purposes; and another group accepted Coase's static-perfect competition assumptions for the sake of argument. Even so, they were able to demolish Coase's claim of allocative neutrality of liability rules. Dolbear [9], Randall [13, 14], and Mishan [11], using static-perfect competition analysis of two-party cases, have made varying degrees of progress toward circumscribing the claimed generality of Coase's allocative neutrality doctrine. Here summarized is the treatment in Randall [14], in which the following propositions are proven mathematically.

In an external diseconomy situation where both the acting and affected parties are consumers, a change in liability rules will change the budget constraint faced by both. Under the L^z rule, the affected party would offer the acting party a bribe. Under the L^f rule, the acting party would offer compensation to the affected party. The relevant budget constraints are under L^z, for the affected party,

$$\overline{Y}_1 - p_1q_{11} - \cdots - p_mq_{m1} - p_n^*(q_{n2}^\circ - q_{n2}) = 0 \tag{1}$$

and for the acting party,

$$\overline{Y}_2 - p_1q_{12} - \cdots - p_mq_{m2} - p_nq_{n2} + p_n^*(q_{n2}^\circ - q_{n2}) = 0 \tag{2}$$

under L^f, for the affected party,

$$\overline{Y}_1 - p_1q_{11} - \cdots - p_mq_{m1} + p_n^*q_{n2}^\circ - p_n^*(q_{n2}^\circ - q_{n2}) = 0 \tag{3}$$

and for the acting party,

$$\overline{Y}_2 - p_1q_{12} - \cdots - p_mq_{m2} - p_nq_{n2} - p_n^*q_{n2}^\circ + p_n^*(q_{n2}^\circ - q_{n2}) = 0 \tag{4}$$

such a market clearly cannot exceed the costs of its operation. The absence of an observable market is, in itself, a market solution. This argument would seem to lead to the conclusion that any externalities which are observed to exist unmodified should not be modified, since transactions costs must therefore be so high that modification is unprofitable. However, the fallacy is obvious. The unprofitability of market solution does not prove that solution by any other method must also be unprofitable. If some other method of solution involves lower transactions costs, solution by that method may be preferable to no solution at all.

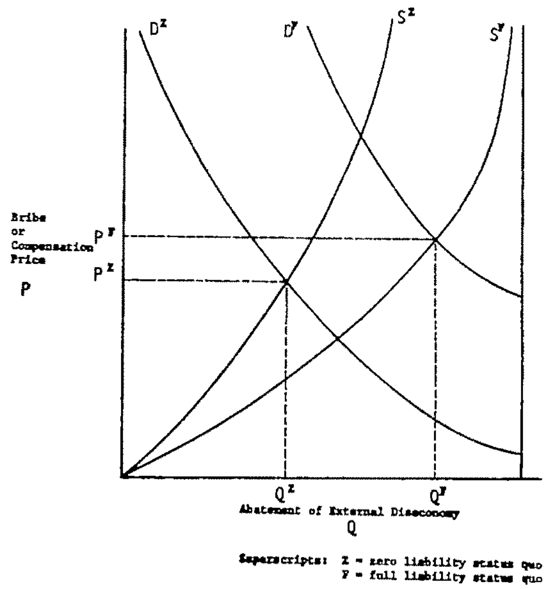

Figure 1. Market solutions to externality in consumption

Source: Randall [13, 14]

where the affected party suffers an external diseconomy from the acting party's consumption of the good n,

$\overline{Y}_j$ is the income of Mr. j,
q_{ij} is the consumption of the good i by Mr. j,
p_i is the competitive market price of the good i,
p_n^* is the unit bribe or compensation price,
and q_{n2}° is the amount of the good n which would be consumed by the acting party if $p_n^* = 0$.

These changes in budget constraints associated with changes in liability rules are sufficient to induce shifts in the resultant demand and supply curves for abatement of the external diseconomy. This is true for all cases, except the very special case where the affected party has an income elasticity of demand for abatement equal to zero and the acting party has a zero income elasticity of demand for the commodity associated with the externality. Figure 1 shows the situation. The L^f rule results in a greater level of abatement of an external diseconomy than does the L^z rule. Where any consumers are involved in an externality situation, the demand or supply curves of abatement associated with those consumers will shift with a change in

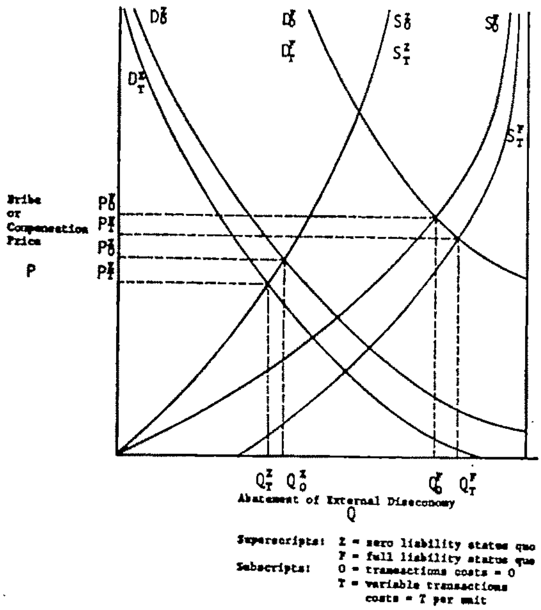

Figure 2. Market solutions to externality in consumption: the effect of transactions costs

Source: Randall [13, 14]

liability rules, resulting in different equilibrium levels of abatement.

In the case of externality in production, a change in liability rules will result in a change in equilibrium output of externality whenever (a) there is an inflexible capital constraint or (b) the use of capital has a positive price. The analysis is similar to that for externality in consumption: a change in liability rules changes the capital constraints affecting both parties. Again, an L^f rule will result in a greater level of abatement than an L^z rule.

Where transactions costs are greater than zero, the party who must pay makes an offer. However, the party who receives payment receives only the amount remaining after transactions costs have been subtracted. As a change in liability rules from L^z to L^f results in the former payer becoming the receiver of payment and vice versa, the assignment of liability affects the equilibrium output of externality when transactions costs are positive. In fairness, it must be noted that Coase [5] recognized that allocative neutrality is predicated upon zero transactions costs.

Figure 2 shows the effect of positive transactions costs on the equilibrium output of externality under the L^z and L^f rules. As unit transactions costs increase, the disparity between the equilibrium solutions under different liability rules increases. It is conceivable, and may often be the case in practice, that transactions costs may be so great that movements away from the starting point defined by the liability law are impossible. In such cases, an L^z law results in zero abatement while an L^f law results in complete abatement of an external diseconomy.

In summary, allocative neutrality with respect to liability rules can be accepted only in situations where all of the involved parties are producers, the use of capital is a free good, and transactions costs are zero. In cases other than these (i.e., in almost every significant externality problem), an L^f rule will result in a market solution specifying a higher degree of abatement of external diseconomies than will an L^z rule.

Mishan [11] makes one further observation, which, although unproven in his article, seems plausible: the incentives for strategies to reduce the effects of external diseconomies are greater under a full liability law. The effects of pollution, for example, can be reduced by emission-reducing technological improvements, or by location of the externality producing business in an out-of-the-way place, or by various other means. Mishan also argues for a full liability rule on the grounds of equity. If polluters are likely to be more prosperous than the affected parties, he argues that a full liability rule would be more equitable than a zero liability rule.

If, following the arguments of Buchanan and Tullock [3] and Olson [12], transactions costs are likely to be larger when negotiations must be initiated by a large and diffuse group of individuals rather than by a much smaller group of individuals who are more vitally interested in this particular issue, it follows that in cases of pollution from industrial sources, an L^z rule is more likely than is the L^f rule to result in transactions costs too high for the achievement of a solution other than the status quo.

The current situation in the theory of market solutions to externality problems can be summarized as follows: A Pareto-relevant externality, being characterized by potential gains from trade, will generate incentives for one or the other of the involved parties to initiate negotiations aimed at modifying that externality. A solution different from the status quo situation may be achieved and, if perfect competition prevails in all relevant industries including the transactions industry, that solution may be Pareto-efficient. However, the resource allocation and income distribution characteristics of the solution achieved are not neutral to the choice of liability rules. In comparison with a

zero liability rule, a full liability rule will result in (1) a higher degree of abatement of an external diseconomy such as pollution, (2) a reallocation of resources toward pollution control and production of commodities which can be produced by low pollution processes, and (3) an income redistribution in favor of the affected party. The effective demolition of the doctrine of allocative neutrality of liability rules removes one of the prime advantages which has been claimed for market solutions to externality problems. The role of the body politic and the bureaucracy in setting the operative liability rule is now known to include the power to affect allocation of resources in production and allocation of budgets in consumption. In a macroeconomic sense, if externalities are as pervasive as is now believed, the power to set liability rules therefore implies the power to affect resource allocation in the whole economy, aggregate production and consumption, and relative and aggregate prices.

Economic Analyses of Observed Market Solutions

Economic analyses of market solutions to externality in practice, unfortunately, seem mostly confined to casual empiricism. As noted above, Demsetz [8] found several externality situations where no market transactions were observed. He attributed this to transactions costs so high that the operation of the market was unprofitable. Alexander [1] mentioned cases involving aluminum refining industries. In some cases market solutions have occurred where the aluminum industry pays compensation to agriculturalists and orchardists on nearby farms. In other cases, the aluminum industry has purchased the land affected by its emissions, creating a merger between acting and affected parties. However, parties less directly affected (e.g., citizens who may suffer some unpleasantness but no loss of agricultural productivity or future generations who may lose the assimilative power of the environment) may not feel that these externalities have been fully internalized.

In a notable exception to this trend of casual empiricism, Crocker [6] presented a reasonably careful regression analysis of market solutions over a time period during which the liability rule effectively changed. He examined a situation in which inorganic fertilizers were produced from locally mined phosphate rock in Polk County, Florida. Damage was observed to local citrus and beef cattle industries over an area of approximately 400 square miles. Prior to 1957, a liability rule not very different from the zero liability rule of the theories presented here was in effect. The only recourse available to the affected parties was civil suit for damages. In such suits, the burden of proof of liability for these damages lay with the plaintiff. The burden of proof had been extremely onerous and no plaintiff had been successful in recovering any damages from the polluting fertilizer companies. Then, in 1957, an Air Pollution Control District was established. Fertilizer companies were in effect advised to buy the affected land or face the prospect of imposition of emission standards.

Crocker obtained and analyzed land sales data for a 20-year period, including 10 years before and 10 years after this effective change in the liability rule. In the earlier period there was a downward trend in land prices, correlated with the decreasing agricultural productivity of the land. However, after the establishment of the Air Pollution Control District, land prices began to rise as the fertilizer companies bought up land in order to avoid the imposition of emission standards. It was also observed that along with a rise in prices of affected land and a gradual but continuous increase in the amount of agricultural land in the ownership of the phosphate companies, the output of polluting emissions by the fertilizer companies was reduced gradually and consistently over the years. Crocker interpreted this reduction in emissions as the result of internalization of the externalities. When the companies owned most of the affected land, their optimum economic strategy was to maximize total returns from both the use of the land and the production of phosphate. No longer could they regard the land and the air above it as a cost-free waste disposal resource.

Crocker's empirical result was that the effective change in liability rules changed the allocative efficiency in the phosphate fertilizer, citrus, and beef industries. He was able to demonstrate that transactions costs were very much higher in the period when the liability situation was essentially L^s than in the later period when the fertilizer companies faced the threat of emissions standards. The change in the liability situation shifted the burden of initiating negotiations from the affected party to the acting party (which group had significantly fewer numbers). Also, the affected party was relieved of the burden of proving damage. Crocker was able to correlate a change in resource allocation

with a change in liability rules and a concurrent change in transactions costs.[4] Significantly, the only detailed empirical study of market solutions to externality which has been completed has demonstrated that a change in liability rules changes resource allocation and the output of pollution emissions.

The Future of Market Solutions

What can be said, then, about market solutions to externality in practice? The theoretical and empirical demonstration that market solutions to externality problems are not allocatively neutral with respect to liability rules may provide some explanation of what has been the major practical objection to market solutions—they are very seldom observed in practice. In the past, laws with respect to externalities such as environmental pollution have been lenient, seldom and ineffectively enforced, or both. In a majority of cases, something approaching a zero liability rule has been in operation. The author's analyses have demonstrated that the zero liability rule is more likely than any positive liability rule to result in zero or low levels of abatement. If market solutions are to be used effectively to ensure environmental quality, the task seems to be that of converting liability rules to L^f, full liability, or to some intermediate position. The important policy question then becomes: are market solutions based on a full or intermediate liability rule preferable to solutions forced by systems of fines and subsidies or standards?

Kneese [10] argues vigorously against reliance upon market solutions on the grounds that market solutions are best adapted (or are adaptable only) to the two-party case, while the environmental quality problem arises from the disposal of wastes into common property resources. One, or a relatively small number of acting parties dumps wastes into a common property resource (e.g., air or water), reducing the welfare of many affected parties. This question can be considered now by briefly examining the operation of market solutions to a pollution problem under a full liability rule. The process of negotiating and enforcing a market solution can be divided into three major steps. It is possible to identify a number of alternative ways these steps can be carried out.

1. The *first step* is enforcement of recognition of the status quo established by an L^f rule. Firms polluting without having obtained the permission of the affected parties must be made to either cease polluting or obtain that permission. This could be done in several ways: **1A:** A public agency could ascertain that some emissions are being released[5] and then, **1A$_1$**, directly impose a very high penalty on the offender unless he ceases polluting or demonstrates he has obtained permission from the affected party, or, **1A$_2$**, ask a court to do the same; or, **1B:** The affected parties could initiate litigation to prove that emissions are being released and seek court enforcement of the L^f rule. Organization could occur in several ways: **1B$_1$**, unanimous action by the affected parties, or, **1B$_2$**, "unanimous" action by a leader or committee after a majority vote of the affected parties; or, **1B$_3$**, a class action initiated by one individual on behalf of the affected parties[6]; or, **1B$_4$**, a series of individual actions by affected parties.

2. The *second step:* The acting party has an incentive to initiate negotiations to induce the affected parties to accept a certain amount of emissions in exchange for compensation. The affected parties must be organized in some way in order to conduct their side of the negotiations. Possibilities are: **2A:** A public agency could bargain on behalf of the affected parties, or, **2B:** The affected parties could bargain in several ways: **2B$_1$**, unanimous action by the affected parties, or, **2B$_2$**, take a "unanimous" position and appoint a representative or committee to bargain, following a majority vote, or, **2B$_3$**, each individual affected could deal separately with the acting party.

3. The *third step* is the policing and enforcement of the agreement made. Compensation payments must be made as agreed and the agreed emission limit must not be exceeded. The possible types of organization of the affected party for this purpose parallel those in **1.**

[4] Crocker interpreted this change in output of pollutants and resource allocation with the change in liability rules as being entirely attributable to the change in transactions costs. The theoretical work by Randall would suggest that the change in liability rules would result in a different solution with respect to pollution emissions and resource allocation even if transactions costs were unchanged. But this is a relatively minor quibble.

[5] Note: A full liability rule requires proof only that emissions are being released. This is a much simpler matter than proving that (a) damage is occurring and (b) the defendant is responsible.

[6] It would be necessary to change the law in most states to allow this.

oats acreage declined. Trends are less evident in sorghum and barley plantings. However, yearly fluctuations were substantial during the Fifties, as acreage restrictions were periodically applied to corn but not to these last two competitive crops.

Land diversion from corn to conservation or other approved uses also competes with corn plantings. This substitution is clearly seen in Figure 1. The figure additionally reveals that diversion has been sizable in recent years. The total corn acreage diversion exceeded barley acreage and sorghum acreage in most years since 1961 and oats acreage in five of the 10 years.

The Analysis

A very general statement of the economic model underlying this investigation is

$$A = f(G, M, Z) \tag{1}$$

where A is corn acreage planted in the United States, G represents government policy provisions such as price support loan rates, direct support payments to growers, and acreage diversion payments, M consists of market influences, and Z includes all other supply determinants and random effects.[3]

Theoretical framework

First consider the components of the government policy term, G, in equation (1). In an earlier paper by Houck and Subotnik [4], the notion of a weighted support rate for policy-influenced crops was developed. This concept was introduced as a means of expressing both acreage restrictions and announced price supports together in a single term subject to empirical measurement or estimation. Figure 2 illustrates this idea. Assume that S is a static acreage supply function for a crop at various price support levels. Acreage is measured along the horizontal axis and support price along the vertical axis. (For simplicity, assume that the position of S for a given crop year is affected by previous *market* prices but not current ones.) At the announced price support of PA, producers

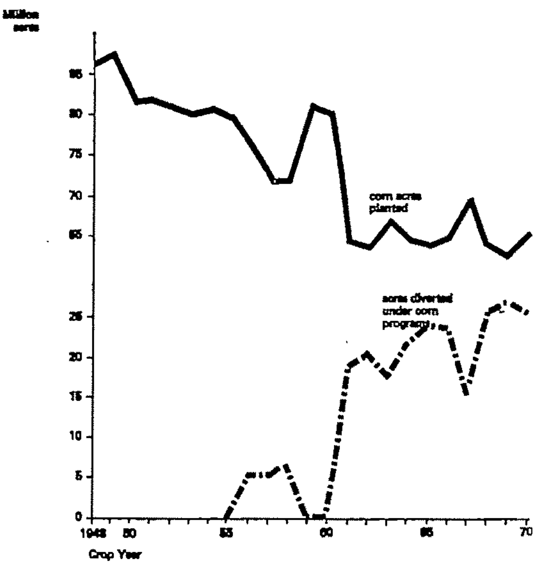

Figure 1. U. S. corn acres planted and diverted, 1948–70

would plant A_1 if there were no restrictions or conditions attached to the price support. But if policy makers wish to reduce acreage to, say, A_2, they could drop the support rate to PF or attach acreage-restricting conditions to obtaining the higher PA so that, on balance, acreage planted falls to A_2. Then PF is the weighted support rate.

The analytical and empirical problem is to find the appropriate weight or adjustment factor to apply to PA to bring it to PF for any given set of program provisions. This adjustment factor, however calculated, is a summary measure of the acreage restricting features of a particular program. Imagine that

$$PF = rPA \tag{2}$$

where PA is the announced support rate available to either voluntary or mandatory program participants, r is the adjustment factor expressing the acreage restrictions in the program, and PF is the weighted support rate. Generally, the range of r is between 0 and 1.0. If no restrictions are attached to obtaining PA, then r is equal to 1.0. The tighter the restrictions, the closer r will be to zero.

The existence of direct payments, as incentive for program participation, adds further complications. Both support payments and diversion payments can be introduced in at least two ways. One way is to assert that payment rates influence r. The larger the payment

[3] The analytical framework and empirical measurements represent only one of many possible ways of investigating corn acreage variations. For instance, economic and other factors affecting changes in per-acre yields are not examined in this paper. Yield changes are assumed to be determined independently of acreage changes. For a comprehensive review of trends and developments in corn yields see [3, pp. 28–32].

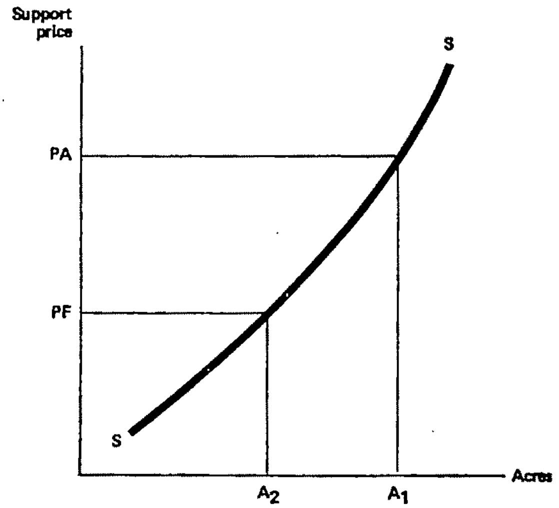

Figure 2. Economic model

rate the smaller r becomes and, hence, the smaller the acreage actually planted, and *vice versa*. Another way is to assert that these payments act as shifters of the function S. An increase in payment rates shifts S to the left and a decrease shifts S to the right. In this paper support payments are handled in the first manner and diversion payments in the second. This decision was based on the treatment of support payments in the voluntary programs up to 1966. Before then support payments were tied to "normal" production on all planted acreage. Thus, the producer's level of support payments (above the loan rate) was a function of his acreage planting decision. Diversion payments were related explicitly to idled land in all annual programs.[4]

Policy makers are assumed to alter program provisions from year to year to either encourage or discourage participation and thus influence corn output in line with production goals. As incentives for participation are changed, farmers move in and out of the program and participants divert more or less land. As program provisions change from year to year, changes can occur in PA, in r, and in the diversion payment schedule. Together these factors determine PF and the position of S. Once these are set, the acreage A is determined, given the underlying price-acreage relationship embodied in S.

Another government policy decision which is assumed to have a major impact on corn acreage is the price support loan rate for soybeans. Soybeans and corn compete for available production resources, including land, in the major corn-growing regions of the United States. With all else constant, a higher loan rate on soybeans will reduce corn acreage and a lower loan rate will stimulate corn acreage.

Next, consider the components of the term M in equation (1). For the purposes of this investigation, the estimated market relationships were not complex. Given a set of government program decisions for crop year t, the planted acreage of corn was assumed to depend upon the open market corn price in the previous crop year, $t-1$, and, in some specifications, the acreage of grain sorghums planted in year t.

The net effect of all other supply determinants and random effects, Z in equation (1), is assumed to be a mean-zero random variable with constant and finite variance over the sample period. Its assumed existence permits the use of ordinary least squares for measuring individual effects of the specified variables.

Empirical measurement of policy variables

Two variables reflecting corn program provisions were calculated for each crop year in the 1948–70 period.[5] The first is an indicator of the weighted price support rate (PF), calculated according to equation (2). Because the adjustment factor (r) cannot be observed, the proportion of the base acreage permitted for corn planting by program participants was selected as a proxy.[6] The second policy variable is a measure of the supply shifter which reflects

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[4] Feed grain programs have tied eligibility for support payments to acreage cutbacks, but this is not necessary conceptually or, in fact, true for all commodities (e.g., wool). Hence, support payments and the loan rate are merely two parts of the announced support price, PA, in equation (2) and Figure 2. Beginning with the 1966 program, however, corn support payments have not applied to total output allowed under the program. Therefore, since 1966, it is just as logical to consider support payments as rent for required land diversion as supplemental payments for production. This implies that both support and diversion payments may be viewed as shifters of S. This latter view may be more valid for future analyses if support payments continue to be restricted to a portion of planted acreage or are made subject only to a total acreage limitation as in the Agricultural Act of 1970.

[5] For this discussion and the analyses which follow, some special program features were not taken into account. These include modifications for small producers (those with less than 26 acres of feed grains) and cross-compliance provisions among various feed grains, wheat, and soybeans. Although these aspects are important for some producers and areas, their aggregate effect was assumed to be reasonably constant or negligible.

[6] See [4, p. 100] for some implications of this method of estimating r.

diversion payment rates (*DP*). The values of *DP* reflect changes in payment levels and eligible diversion acreage. An increase in either factor, holding the other constant, raises the value of *DP* and thus reduces corn acreage by shifting the corn acreage supply function to the left.

Programs provided for a range of permitted planting and eligible diversion acreage during most years in the 1960's. This was accounted for by averaging *PF* and *DP* for minimum and maximum permitted planting and diversion. The average is the simplest way to enable the policy variables to move when either the maximum or minimum program provisions were altered. Different program provisions in the 1950's necessitated modification of the calculations of *r* and *DP*. Similar lines of reasoning were applied and the computations are as nearly comparable with the later years as possible. Figure 3 compares *PF* with *PA* and the loan rate.[7]

[7] The construction of the policy variables, *PF* and *DP*, of necessity are arbitrary. Many defensible methods of estimating the adjustment factor, *r*, and the diversion payment measure, *DP*, surely could be devised. Several have been suggested by reviewers and colleagues. Perhaps the most useful way to regard these constructed variables is to view them as indicators or proxies for their theoretical counterparts and not as attempts to measure them precisely. However, the empirical evidence presented here suggests that these variables, as computed, contribute appreciably to the explanation of changes in corn acreage. Details of the calculations may be obtained from the authors.

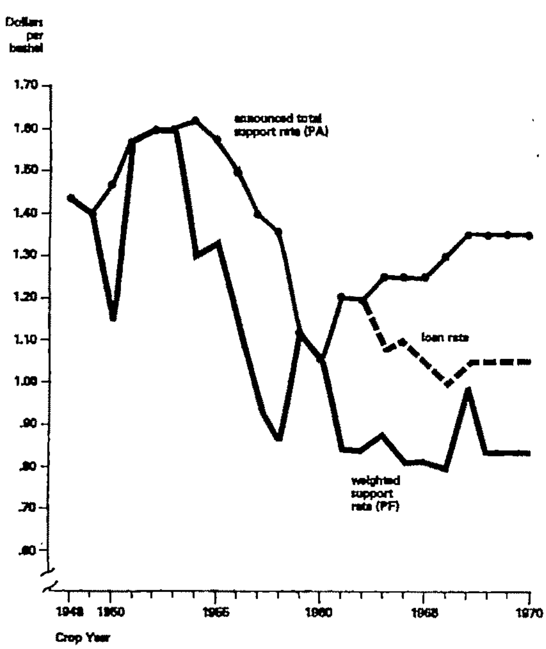

Figure 3. U. S. average total support rate and weighted support rate, 1948–70, and loan rate, 1962–70

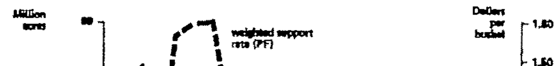

Figure 4. U. S. corn acres planted, weighted support rate and diversion payment rate, 1948–70

Figure 4 illustrates the relationships among *PF*, *DP*, and acreage planted. The inverse relationship between *PF* and *DP* indicates that adjustments in program features have been complementary. That is, increasing incentives to plant corn have corresponded with decreasing incentives to divert land from corn production and *vice versa*. Both the downward trend in acres planted and yearly changes in plantings are associated positively with *PF* and negatively with *DP*.

The validity of *DP* as a supply-inducing price for land diversion was established by estimating corn acres diverted as a function of *DP*. Equation (3) depicts the results of a least squares regression of first differences for the two variables for the 1956–70 period.[8]

$$\Delta AD = 1{,}290 + 82{,}183\Delta DP \qquad (3)$$

$$(10.5)$$

$$R^2 = .90$$

where

AD = Corn acreage diverted under the feed grain program, in thousand acres.

[8] For a more detailed approach to this general idea see the Miller and Hargrove report [6].

DP = Diversion payment rates, weighted by eligible diversion acreage, in dollars per bushel.

The t-value is in parentheses.

Estimates in equation (3) indicate that acres diverted are increasing by nearly 1.3 million yearly due to unmeasured factors, but annual changes in diversion are closely associated with DP. A 10-cent increase in DP was associated with an increased diversion of 8.2 million acres.

Empirical Results

Corn acreage supply functions for the United States using these policy variables were estimated by ordinary least squares. The statistical estimation encompasses 21 crop years, from 1949 through 1969. The discussion in this section of the paper begins with two special considerations which have important implications for the estimated functions. One is the historical relationship between market prices for corn and the variable PF. The other is the relationship in both acreage and policy between corn and grain sorghum.

Market prices versus support rates

In supply analyses for agricultural products, lagged market prices frequently are assumed to be the relevant supply-inducing price. In the theoretical framework of this paper, such a relationship between lagged market price and corn acreage was postulated. However, the presence of government price supports makes the *net* relation between lagged market prices and acreage difficult to isolate.

One reasonably successful attempt to measure separate effects of market prices and support prices involved acreage supply analyses for soybeans [4]. The results generally indicated greater acreage responsiveness to lagged market prices than to current price supports. This is not surprising since, during the period studied, soybean market prices exceeded support prices in most years.

A contrasting situation exists for corn. Since 1948, the market price exceeded the loan rate (or loan plus support payment) in only two years. Hence, as might be expected, the variations in the weighted support price variable, PF, were found to explain variations of corn acreage better than the lagged market price. Moreover, intercorrelation between these two independent variables reduced the significance of both when they were entered in the same regression equation. Owing to these difficulties, the statistical relationship between the two price series was examined for the 1949–69 period, equation (4).

$$PF_t = .1717 + .8983P_{t-1} - .0185T \qquad (4)$$
$$\qquad\qquad\qquad (4.9) \qquad\qquad (3.4)$$
$$R^2 = .86 \qquad\qquad \bar{s} = .11$$

where

PF_t = weighted support rate for corn in crop year t, dollars per bushel

P_{t-1} = market price of corn received by farmers in crop year $t-1$, dollars per bushel

T = linear trend (1949 = 1, 1950 = 2, etc.)

$\bar{s}$ = standard error of the estimate.

The values in parentheses are t-values.

According to this estimated equation, a given change in the market price was associated with a similar change in PF in the next crop year about 90 percent as large as the market price change adjusted for a negative secular trend.

These results suggest a possible interpretation of the policy decision-making history for feed grains. One could argue that policy makers adjust the terms of the price support program for the coming crop year largely on the basis of immediate past experience. For instance, a large crop in year $t-1$ depresses the market price, P_{t-1}. Policy makers desire to reduce production, and hence, supplies for the following year. Reducing PF_t is one tool to achieve this end.

Based on these results, the intercorrelation problem, and the analytical emphasis on policy variables, lagged market prices do not appear in the following supply equations. In future work this approach may be inappropriate if the influence of market prices continues to strengthen.

Corn-sorghum acreage substitution

Prior to 1961 sorghum acreage was not restricted. A farmer could plant any amount he wished and still obtain a sorghum price support loan. Also, farmers who reduced corn acreage as required for corn support loans could plant sorghum without restriction. During the years in which these liberal provisions applied, sorghum acreage increased sharply in some principal corn areas, especially in the southwestern portion of the Corn Belt and Southern Plains states.

Beginning with the 1961 Feed Grain Program, corn price supports could no longer be btained by farmers if sorghums were planted n acres diverted from corn. Furthermore, orghum acreage was restricted as a qualification for sorghum supports. These policy changes vere hypothesized to alter the corn-sorghum elationship at this point in the study period.

Three analytical approaches were explored o relate sorghum and corn acreages. The basic ssumption is that corn and sorghum acreages vere much more substitutable before 1961 than fter. Sorghum acreage rather than market or upport prices was employed because of the tie etween sorghum and corn support prices and rograms. A fixed relationship between the two rices has been maintained by policy makers. t was decided therefore that acres planted vould reflect more clearly whatever substitution existed.

The first approach involves including sorghum acreage as an independent variable prior o 1961 and then setting the variable equal to ero in the 1961–69 period. The second approach is similar except that from 1961 to 1969 orghum acreage was set at the mean value of he previous 12 crop years. The third approach nvolves splitting the data into two periods nd then estimating the supply equations eparately. For this purpose, the 21-year study period was split between 1959 and 1960 when neither corn nor sorghum acreage restrictions applied. The first of these two "restriction free" years was included with the first period and the second with the latter period. The results are presented as part of the supply analyses which follow.

Supply equations

Using the analytical model, the policy variables, and the sorghum-corn relationships discussed in previous sections, several nationwide corn acreage supply equations were estimated by least squares. The results of six of these estimations are shown in Table 1. Five of the equations employed actual values of the variables and one employed first differences.

Generally speaking, the signs of the estimated coefficients are consistent with prior expectations, the estimated coefficients are reasonably large relative to their calculated standard errors, and the overall fit of the equations, indicated by R^2, is good.

Corn program policy variables, *PF* and *DP*, contribute importantly to the explanation of changes in acreage planted. A 10-cent increase in *PF* results in an estimated 939 to 1,026 thousand acre increase in planted acreage. The estimated effect of *DP* is about four times greater. A 10-cent increase in *DP* is associated

Table 1. Estimation of U. S. corn acreage planted, 1949–69 (regression coefficients and *t*-values)

Equation	Time period	No. of observations	Constant	*PF*	*DP*	*PF-DP*	*PSS*	*AGM*	*AGO*	*DV*	*T*	R^2	$\bar{s}$
Dependent Variable = *A*													
I-1	1949–69	21	100,256.34	10,226.48 (3.8)	−40,894.56 (6.7)		−11,313.21 (6.4)	−.30 (3.1)			−319.61 (3.4)	.983	1,188.92
I-2	1949–69	21	100,320.04	10,263.74 (3.6)	−41,239.72 (5.0)		−11,377.19 (5.5)		−.29 (2.6)	−5,287.55 (1.5)	−325.72 (2.4)	.983	1,230.46
I-3	1949–69	21	93,183.44			18,558.87 (9.1)	−14,321.24 (6.7)	−.20 (1.6)			−169.77 (1.5)	.968	1,603.65
I-4	1949–59	11	101,880.04			15,285.16 (6.9)	−15,167.65 (7.1)	−.34 (3.1)			−189.61 (1.2)	.964	1,030.12
I-5	1960–69	10	67,564.18			27,049.12 (9.0)	− 5,242.09 (1.7)				−491.34 (2.6)	.960	1,270.20
First Differences of All Variables													
I-6	1949–69	21	−448.88	9,386.36 (4.3)	−45,183.79 (7.4)		− 9,932.47 (5.4)	−.25 (2.2)				.939	1,306.33

Variable Descriptions

A = U. S. acreage of corn planted, in thousands
PF = U. S. average corn loan rate (plus direct support payments, 1963–69), weighted by acreage restriction requirements, dollars per bushel
DP = corn acreage division payment rate, weighted by eligible diversion acreage, dollars per bushel
PF-DP = *PF* minus *DP*
PSS = U. S. average soybean price support loan rate, dollars per bushel
AGM = U. S. acreage of sorghums planted for 1949–60 and the mean of 1949–60 acreage for 1961–69, in thousands
AGO = U. S. acreage of sorghums planted for 1949–60 and 0 for 1961–69, in thousands
DV = 0 in 1949–60 and 1 in 1961–69
T = linear trend ((1949 = 1, 1950 = 2, etc.)
$\bar{s}$ = standard error of the estimate.
The values in parentheses are *t*-values of the regression coefficients.

with a 4.1 to 4.5 million acre decrease in planting. When interpreting the relative effects of these constructed variables, recall that *PF* values are considerably greater than those of *DP*. Thus, the influence on corn acreage of *PF* exceeds that of *DP*. However, if the effects of *PF* and *DP* are assumed to be equal but in opposite directions, the use of the *PF–DP* variable is appropriate. When *PF–DP* is used, the value of the resulting coefficient lies between the coefficients on *PF* and *DP*, estimated as separate variables. Planted acreage would increase by 1.9 million if *PF–DP* increased by 10 cents, according to equation (I-3). Of course, this could result from either an increase in *PF*, a decrease in *DP*, or some combination of the two.

The separate estimation for 1949–59 and 1960–69, equations (I-4) and (I-5), reveal different effects in the two periods. The impact of changes in the policy variables was greater during the Sixties when acreage diversion payments were more common. Low t-values were obtained when *PF* and *DP* were estimated separately for 1960–69, probably due to intercorrelation. Coefficients of *PF* and *DP* estimated for 1949–59 were approximately the same magnitude as those reported for the entire 21 years.

The magnitude of the coefficients of *PF*, *DP*, and *PF-DP* remains relatively constant in all specifications. Note that the effect of *DP* on acreage planted, Table 1, is about one-half its opposite estimated effect on acreage diverted, equation (3). This is consistent with observations by USDA officials that, under the past programs, more land was diverted than the actual reduction in feed grain acreage. They call this phenomenon "slippage" [2].

Soybeans compete with corn for production resources since corn land is also generally desirable for growing soybeans. The support price of soybeans is entered in the corn supply model to measure this substitution. During this study period no acreage limitations were placed on soybeans, therefore no weighting was necessary and *PSS* is the announced loan rate. As estimated for the 21-year period, a 10-cent increase in *PSS* leads to a 1.0 to 1.4 million acre decrease in corn plantings. Estimates of *PSS* coefficients for the shortened time series vary between the two periods. The *PSS* coefficient for 1960–69 is less than half the size of other *PSS* estimates. However, its low t-value suggests that it is relatively less reliable than the other estimates.

Grain sorghum is another important substitute for corn. As mentioned, changes in corn and sorghum programs midway in the study period suggested the need for a detailed examination of this relationship. Sorghum acreage variables *AGM* and *AGO* assume substitutability with corn acreage prior to 1961 but not from 1961 to 1969. The results are nearly identical from both variables. They indicate that a one-acre increase in sorghum planting during 1949–1960 reduced corn acreage by 0.2 to 0.3 acres. Results from the split time series, equation (I-4), are similar. This means that either *AGM* or *AGO* is an acceptable approach to the sorghum-corn substitution problem.

A dummy variable was added to equation (I-2) in which sorghum acreage was set at zero for 1961–69. Its coefficient, −5,287.55, is subtracted from the constant for the years 1961–69. The t-values for regression coefficients in equation (I-2) are smaller than those in equation (I-1). Intercorrelation between *AGO* and *DV* in equation (I-2) may be responsible. The simple correlation coefficient (r) is −.94. These smaller t-values, along with a larger standard error ($\bar{s}$), indicate that equation (I-1) may be a slightly more reliable estimator.

A trend variable is included to account for changes occurring through time which are not reflected by the other variables. The estimated coefficients indicate an annual decrease of 170 to 326 thousand acres throughout the 21-year period. Estimates for the split series indicate that the decline in corn acreage associated with trend during the Sixties was more rapid than in 1949–59.

Equation (I-6), the first difference model, in effect removes from all variables whatever linear trend is present. The constant term reflects the trend influence. The annual decrease due to trend was 449 thousand acres, larger than the effect in the models using actual values. Coefficients for the remaining variables were changed only slightly by the first difference transformation.

Concluding Comments

The major objective in this paper was to formulate and estimate U. S. corn acreage supply functions for the 1949–69 period. The principal focus was on the development and use of variables to reflect the effects of govern-

ment price support and acreage restricting programs during this period. Support rates were adjusted to account for acreage controls in various annual programs. Diversion payments available to program participants also were introduced. Price supports for soybeans and measures of corn-sorghum acreage competition were employed to capture substitution relationships among the major competitors on the supply side.

Generally speaking, the variables used and the equations estimated provided encouraging results. More than 95 percent of the variation in U. S. corn acreage during this 21-year period can be associated with the selected variables. The equations and the variables are summarized in Table 1. Although the estimation was based on data from 1949 to 1969, equation I-1 (Table 1) was used to "predict" 1970 and 1971 corn acreage. Actual data on the independent variables were inserted in the equation and the solutions for corn acreage computed.

The estimated value was 67,409 thousand acres and the actual 1970 corn acreage was 67,352 thousand acres. For 1971, estimated and actual values were 72,148 thousand acres and 74,651 thousand acres, respectively. The estimate, however, does not account for program changes in 1971 that tend to increase planting compared with previous years. Adjustments to reflect discontinuation of incentives for total acreage diversion by small farms and to account for less restrictiveness on corn planting would move the estimate quite close to actual 1971 acreage.

References

[1] BRAY, JAMES O., AND PATRICIA WATKINS, "Technical Change in Corn Production in the United States, 1870–1960," *J. Farm Econ.* 46:751–765, Nov. 1964.

[2] BRUNTHAVER, CARROLL G., "Implications of New Farm Legislation," paper presented at National Outlook Conference, USDA, Washington, D. C., Feb. 23, 1971.

[3] CLOUGH, MALCOLM, "Trends and Variations in Corn Yields over the Past 50 Years," *Feed Situation*, Economic Research Service, U. S. Department of Agriculture, Feb. 1968.

[4] HOUCK, JAMES P., AND ABRAHAM SUBOTNIK, "The U. S. Supply of Soybeans: Regional Acreage Functions," *Agr. Econ. Res.* 21:99–108, Oct. 1969.

[5] HUSHAK, LEROY J., "A Welfare Analysis of the Voluntary Corn Diversion Programs, 1961–1966," *Am. J. Agr. Econ.* 53:173–181, May 1971.

[6] MILLER, THOMAS A., AND STANLEY H. HARGROVE "Factors Affecting Acreage Diverted under the U. S. Feed-Grain Program," Economic Research Service, U. S. Department of Agriculture, in cooperation with Colorado State University Agricultural Experiment Station, ERS-453, Nov. 1970.

[7] U. S. Department of Agriculture, Agricultural Stabilization and Conservation Service, *Farm Commodity and Related Programs*, Agr. Handbook 345, 1967.

[8] ———, Agricultural Research Service, *Farm Production: Trends, Prospects and Programs*, Agr. Infor. Bull. 239, May 1961.

[9] ———, Economic Research Service, *Feed Situation*, various issues, 1947–1970.

[10] ———, ERS, *Feed Statistics*, Stat. Bull. 410, Sept. 1967; supplement for 1969, Oct. 1969.

A Truncated Maximin Approach to Farm Planning Under Uncertainty with Discrete Probability Distributions*†

Yoshihiro Maruyama

A method is presented for solving linear programming problems under the assumption that input-output, restraint, and functional coefficients follow a discrete joint probability distribution. This may be a rather plausible assumption in some uncertain farm planning contexts. The objective function is formulated in terms of variance and/or expectation. Special attention is given to the most adverse outcomes with respect to both the functional value and side constraints. Parametric analysis can be used to determine trade-offs among the functional value, the adversity level, the tolerance probability, and the probability of infeasibility. Finally, the proposed method is applied to a farm problem.

As linear programming has been widely recognized as a useful method in farm planning, the necessity of incorporating uncertainty into the programming model has been acutely realized. Failure to incorporate uncertainty into the input-output, restraint, and functional coefficients has often resulted in an excessive specialization in a small number of farming activities and associated unstable gross margins, which the farmer concerned is neither willing nor able to accept. Incorporating uncertainty in general into the programming model is a very difficult task. However, if uncertainty in these coefficients can be approximated by a discrete joint probability distribution, i.e., if these coefficients take on only a finite set of "possible" values, the task becomes less formidable. In fact, a considerable number of "linear programming models under uncertainty" in varying degrees of generality have been developed [4, 5, 8, 11, 13, 19, 23, 28].

Among these, Cocks [5] has developed a very clear-cut formulation. His method involves the introduction of allocating factors similar to Tintner's [32] and further lamination of the program to represent separately all possible situations or states of nature where the relevant coefficients take on different sets of values. The required number of additional variables and constraints generates a very large program and temporarily limits practical applications, especially when uncertainty in the restraint coefficients is also taken into account (which is not attempted in his paper [5]).

On the other hand, Madansky [19] concentrates on uncertainty in the input-output and restraint coefficients. He notes that when these coefficients are subject to a discrete probability distribution both the left-hand and right-hand sides of each constraint take on a finite number of possible values so that the uncertainty concerned can be completely specified in a finite number of deterministic constraints. He defines this approach as the "fat" solution to the linear programming problem under uncertainty.

A third group of approaches relevant here is associated with the attempts by Hazell and How [12, 13], Maruyama and Kawaguchi [17, 23], and others, which are mainly concerned with uncertainty in the functional coefficients and which pay their special attention to the worst possible functional value and other measures of uncertainty. Characteristic of these approaches is their emphasis on the investigation of trade-offs between the expected and the worst possible functional values instead of being content with finding a single "optimum" program. These approaches constitute a parametric extension of earlier attempts [15, 26, 27] based on the constrained game [2, 24]. Relevance of the parametric analysis can be justified by (a) the apparent difficulty in revealing the farmer's aversion or preference

* The title of Van Moeseke's earlier work [33] suggests an approach similar to ours, but his approach actually draws upon fractiles, as will be discussed. The term "uncertainty" is used here according to the recent practice as distinct from Knight's and represents the state of a decision maker's knowledge with respect to the future events, where he is not certain which one of all conceivable events will actually occur. But he is somehow able to assign his personal probabilities or to distinguish the degrees of his belief among all conceivable events which are likely to occur.

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Yoshihiro Maruyama *is an associate professor in the Department of Agricultural Economics, Faculty of Agriculture, Kyoto University.*

toward uncertainty and (b) the insufficient reliability of the basic informational inputs, as is often the case in many practical farm planning applications.

The purpose of this paper is to graft the two-parameter approach of the third group to Madansky's "fat" formulation and extend the former to the side constraints as well. More specifically, this paper attempts to incorporate uncertainty in all of the functional, restraint, and input-output coefficients. It also investigates trade-offs between the expected functional value and the worst possible functional value and between the probability of infeasibility (i.e., the probability that all of the side constraints are not satisfied) and other measures of uncertainty. Finally, the proposed method will be applied to an example of a mixed farm to illustrate further aspects of this method.

Significance of the worst possible outcome has been emphasized by many authors for various but closely related reasons. In the approaches based on the "safety first" principle, Roy [29] presumed the existence of a disaster level d with respect to the functional value z. Any outcomes below this disaster level would imperil the decision maker to the point that he would tend to minimize the probability of ruin, i.e., the probability that such adverse outcomes might eventuate.

$$\text{Prob. } [z < d]. \tag{1}$$

Telser [31] allowed a tolerance probability p that the anticipated outcomes might fall short of the given disaster level,

$$\text{Prob. } [z < d] \leqq p, \tag{2}$$

and tried to maximize the expected outcome under this probability constraint. An attitude similar to Telser's is explicit and applied to the side constraints as well in the approach of chance-constrained programming [3, 16]. In those approaches based on the lower confidence limit or fractile [1, 30, 33], the fractile f corresponding to the preassigned tolerance probability p,

$$\text{Prob. } [z < f] \leqq p, \tag{3}$$

is maximized so that the functional value may fall short of the calculated fractile level at most with the tolerance probability.

Significance of the worst possible outcome has been emphasized also in connection with the state of the decision maker's knowledge relative to the problem he faces. In the situation of ambiguity or partial ignorance [9, 18] where some estimates of the probability that each state of nature eventuates are available but not completely reliable, the decision maker will not rely completely upon the expected outcome but on some weighted average of the expected outcome and the anticipated worst possible outcome which appears more reliable to him.

Formulation of the Model

Consider a linear programming problem of maximizing

$$z = c_1x_1 + \cdots + c_nx_n \tag{4}$$

subject to

$$s_i = a_{i1}x_1 + \cdots + a_{in}x_n \leqq b_i, \quad i = 1, \cdots, m \tag{5}$$

and to

$$x_j \geqq 0, \quad j = 1, \cdots, n. \tag{6}$$

In the corresponding linear programming problem under uncertainty with discrete probability distributions, a_{ij}, b_i, and c_j are random variables which take on a finite number of "possible" values, a_{tij}, b_{ti}, c_{tj}, $t=1, \cdots, T$, respectively, with associated probability y_t, $t=1, \cdots, T$.

$$\text{Prob. } [a_{ij} = a_{tij},\ b_i = b_{ti}, \text{ and } c_j = c_{tj}] = y_t \geqq 0. \tag{7}$$

$$\sum_{t=1}^{T} y_t = 1. \tag{8}$$

Therefore, the resource requirements s_i and the functional value z of a given program $x_1, \cdots, x_n$ are also random variables that take on a finite number of possible values, s_{ti} and z_t, $t=1, \cdots, T$, respectively, with the corresponding probability y_t, $t=1, \cdots, T$.

$$s_{ti} = a_{ti1}x_1 + \cdots + a_{tin}x_n, \quad t = 1, \cdots, T; i = 1, \cdots, m. \tag{9}$$

$$z_t = c_{t1}x_1 + \cdots + c_{tn}x_n, \quad t = 1, \cdots, T. \tag{10}$$

If each resource requirement is confined in all circumstances within the corresponding restraint that is also random but independent of the decision variables $x_1, \cdots, x_n$, then

(11) $s_{ti} \leqq b_{ti}, \; t = 1, \cdots, T; i = 1, \cdots, m.$

The set of programs defined by (6) and (11) corresponds to the "permanently feasible" set in Madansky's sense [19].

The mathematical expectations of relevant coefficients and functional value are listed below for subsequent reference.

$$\text{(12)} \quad \text{Expt.}\,(a_{ij}) = \bar{a}_{ij} = \sum_{t=1}^{T} y_t a_{tij}, \quad i = 1, \cdots, m; j = 1, \cdots, n.$$

$$\text{(13)} \quad \text{Expt.}\,(b_i) = \bar{b}_i = \sum_{t=1}^{T} y_t b_{ti}, \quad i = 1, \cdots, m.$$

$$\text{(14)} \quad \text{Expt.}\,(c_j) = \bar{c}_j = \sum_{t=1}^{T} y_t c_{tj}, \quad j = 1, \cdots, n.$$

$$\text{(15)} \quad \text{Expt.}\,(z) = E = \bar{c}_1 x_1 + \cdots + \bar{c}_n x_n.$$

E can be maximized subject to the constraints (6) and (11). The corresponding linear programming problem will be referred to as the *expected value problem*.[1] It can be assumed that a solution to this problem exists and that the associated functional value is equal to $\overline{E}$.

If the functional value does not fall short of a preassigned adversity level d in all circumstances, then

$$\text{(16)} \quad z_t \geqq d, \qquad t = 1, \cdots, T.$$

The linear programming problem of maximizing E subject to the constraints (6), (11), and (16) will be referred to as the *truncated maximin problem*. Solutions for various values of d can be obtained by means of the parametric linear programming procedure (PLP). Markowitz [20] suggests a similar approach for the case where neither a_{ij} nor b_i are random.

Deviations in the possible values of restraint coefficients from their respective expectations,

$$\text{(17)} \quad v_{ti} = \bar{b}_i - b_{ti}, \quad t = 1, \cdots, T; \; i = 1, \cdots, m,$$

are defined as downward variability. The maximum of these for each restraint over all states of nature,

$$\text{(18)} \quad v_i = \max\,(v_{1i}, \cdots, v_{Ti}), \; i = 1, \cdots, m,$$

can be used as a measure of variability in the restraint coefficient concerned. Constraints (11) are conveniently parametrized in terms of these v_i's and an additional parameter q,

$$\text{(11.1)} \quad s_{ti} \leqq \bar{b}_i - qv_i, \; q = \text{param.}, \quad t = 1, \cdots, T; \; i = 1, \cdots, m.$$

The associated linear programming problem of maximizing E subject to the constraints (6), (11.1), and (16) will be referred to as the *truncated minimax constraint problem*. Solutions for various values of q and given value of d can be obtained by PLP. Alternatively, solutions for a given value of q and various values of d can be similarly obtained.

The constraints (11) may be too stringent to many decision makers. They may be willing to break some constraints insofar as the gain in gross margins outweighs the losses associated with the caused infeasibilities. They first choose a program $x_1, \cdots, x_n$ which may be feasible in some but not all states of nature. As some one state of nature has actually eventuated, they observe the amounts of shortages $x_{n+T(i-1)+t} \geqq 0, t=1, \cdots, T; i=1, \cdots, m$ and fill them at the unit costs $e_{ti} \geqq 0, \; t=1, \cdots, T; \; i=1, \cdots, m$, which are assumed to be constant. e_{ti} also corresponds to the "cost of shortage" in Evers [10] and the "infeasibility cost" in Hanf [11]. It should be clear that what has been shown here is the "slack" solution formulation of Madansky [19]. The constraints (11) are now rewritten:

$$\text{(11.2)} \quad \begin{aligned} s_{ti}^* &= s_{ti} - x_{n+T(i-1)+t} \leqq b_{ti}, \\ x_{n+T(i-1)+t} &\geqq 0 \\ t &= 1, \cdots, T; i = 1, \cdots, m. \end{aligned}$$

The associated functional value in the tth state of nature is similarly rewritten:

$$\text{(10.2)} \quad \begin{aligned} z_t^* = c_{t1}x_1 + \cdots + c_{tn}x_n - e_{t1}x_{n+t} \\ - \cdots - e_{tm}x_{n+T(m-1)+t}, \\ t = 1, \cdots, T. \end{aligned}$$

If it is impossible to make up the shortages in some resources arising in certain states of nature, either the corresponding shortage variables will have to be set to zero or the cor-

[1] As will be shown, this is different from Madansky's "expected value" formulation where all coefficients in the problems (4)–(6) are replaced by their mathematical expectations.

responding cost will have to be made prohibitively high. If all resources are such that it is impossible to fill their shortages arising in any states of nature, the situation will then be one where only the truncated minimax constraint formulation is relevant.

The associated expected functional value,

$$E^* = \bar{c}_1 x_1 + \cdots + \bar{c}_n x_n - y_1 e_{11} x_{n+1} - \cdots - y_T e_{Tm} x_{n+Tm}. \tag{15.2}$$

The functional value z^* may be required not to fall short of a preassigned adversity level d in all circumstances, i.e.,

$$z_t^* \geqq d,\ t = 1, \cdots, T, \tag{16.2}$$

and to maximize the expected functional value E^* under the condition that any shortages in resources are fulfilled in all circumstances (11.2). Then the truncated maximin problem will again be faced in an augmented form. It should be noted that the relevant programs now consist of the vectors of original activity levels plus the amounts of shortages to be fulfilled, i.e., $x^* = (x_1, \cdots, x_n, x_{n+1}, \cdots, x_{n+Tm})$. This formulation provides an alternative to the above truncated minimax formulation in treating uncertainty in the input-output and restraint coefficients. The adversity level d now takes into account uncertainty in these coefficients as well as in the functional coefficients. A similar treatment of uncertainty in these coefficients is also given by Maruyama and Kawaguchi [25]. To distinguish this formulation from the regular truncated maximin formulation in the above, it will be referred to as the *truncated maximin problem in the "slack" solution formulation*, although this nomenclature is admittedly not very appropriate.

The objective function can be formulated in terms of variance and expectation of z or z^*.

$$\hat{z} = \text{Expt. }(z) + k \text{ Var. }(z), \quad k = \text{param.} \neq 0, \tag{19.1}$$

$$\hat{z}^* = \text{Expt. }(z^*) + k \text{ Var. }(z^*), \quad k = \text{param.} \neq 0. \tag{19.2}$$

The problem then becomes one of quadratic programming for which several efficient solution procedures are available. The relevant constraints for objective function (19.1) are (6), (11) or (11.1), and (16). For (19.2) they are (6), (11.2), and (16.2). Either quadratic programming problem will be referred to as the ***generalized E-V efficient set problem*** or ***risk programming problem***. Solutions to the problem will explore the effects of uncertainty in the input-output, restraint, and functional coefficients and the preassigned adversity level on the E-V efficient (or risk) programs [14, 20].

After further complications of the program to prevent activities assigned to different dates from being operated simultaneously, the above formulations can be applied to farm planning where multistage resource allocation is involved. For an example of such complications, see Cocks [5].

Discussion of the Model

Multiplying both sides of the inequalities (16) by y_t and summing over all t,

$$\sum_{t=1}^{T} \sum_{j=1}^{n} y_t c_{tj} x_j \geqq d \sum_{t=1}^{T} y_t = d. \tag{20}$$

By (14) this relation can be rewritten as

$$\sum_{j=1}^{n} \bar{c}_j x_j \geqq d.$$

The existence of a solution $\bar{E}$ to the expected value problem above implies the existence of a maximum value of d under the constraints (6), (11), and (16) which can be denoted by $\bar{d}$. Thus, the left-hand side of (20) can be regarded as the pay-off of a constrained game [2, 24],[2] where (a) the pure strategy $x_1, \cdots, x_n$ of the maximizer, the decision maker in question, is subject to the constraints (6) and (11), and where (b) the mixed strategy $y_1, \cdots, y_T$ of the minimizer, Nature, is subject to the regular constraints (7) and (8). The value of this game is equal to $\bar{d}$. A similar remark holds for the truncated maximin formulation in the "slack" solution formulation.

In the truncated maximin problem E will attain $\bar{E}$ for sufficiently small values of d, such as a negative number with a very great absolute value. The maximum of such d values can be denoted by $\underline{d}$. In the context of the above

[2] Constrained games are usually considered to arise when the mixed strategies of players are subject to further linear inequalities. In our case the strategies of players are subject to the linear inequalities but not necessarily to the probability (or unit sum) constraint. Charnes [2] has established the equivalence between the constrained game and the linear programming in the mixed strategy case, while the present author and Kawaguchi [24] have established a similar equivalence in the generalized case as shown in the above.

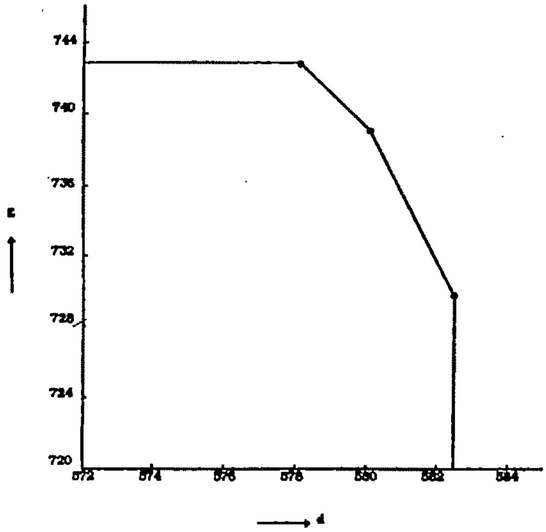

Figure 1. Expectation-adversity level efficiency locus

constrained game, solutions corresponding to $\bar{d}$ guarantee the maximum level of security, while those corresponding to _ guarantee the maximum expectation $\bar{E}$ with respect to the functional value. Solutions corresponding to the intermediate values of $d(\underline{d}<d<\bar{d})$ will offer some weighted averages of these two extremes. The resulting E-d efficient set of programs (Fig. 1) describes the possible trade-offs between the expectation and the adversity level open to the decision maker. The close correspondence between the E-d efficiency criterion and Ellsberg's decision rule [9] should be obvious. These remarks should hold for the truncated maximin problem in the "slack" solution formulation as well.

By use of surplus variables, $u_t \geq 0$, $t=1, \cdots, T$, constraints (16) can be rewritten as equalities,

$$(16.1) \quad z_t = u_t + d, \qquad t = 1, \cdots, T.$$

PLP determines the value of u_t for all $d(\underline{d} \leq d \leq \bar{d})$ [Table 4]. Then the sum $u_t + d$ can be compared with an arbitrary disaster level, for example, h. The sum of y_t's over all t such that $u_t + d < h$ is equal to the probability that the functional value of the program $x_1, \cdots, x_n$ falls short of h, i.e., the probability of ruin. Similarly, the constraints (11.1) can be made into equalities with the introduction of slack variables, $w_{ti} \geq 0$, $t=1, \cdots, T$; $i=1, \cdots, m$,

$$(11.1.1) \quad \begin{aligned} s_{ti} + w_{ti} &= \bar{b}_i - qv_i, \quad q = \text{param.}, \\ t &= 1, \cdots, T; i = 1, \cdots, m. \end{aligned}$$

Then the value of $\bar{b}_i - qv_i - w_{ti}$ can be compared with each corresponding b_{ti}, respectively. The sum of y_t's over all t such that $\bar{b}_i - qv_i - w_{ti} > b_{ti}$ for some i (or alternatively, $x_{n+T(i-1)+t} > 0$ for some i) represents the probability that some of the random resource requirements on the left-hand side of (11.1) [on the first part of the left-hand side of (11.2)] are not satisfied by the corresponding random restraints, i.e., the probability of infeasibility [19]. Thus, the resulting pairs of expectation and probability of ruin (infeasibility) will give insight into the possible trade-offs between the expectation and tolerance probability with respect to both the functional value and the side constraints. Possible trade-offs between the adversity level and the tolerance probability for a given level of expectation can be similarly examined.

Application of the proposed approach to practical farm planning problems requires estimates of the relevant coefficients and their associated probabilities. These are admittedly not easy to obtain and raise statistical problems beyond the scope of this paper. A practical approach would be to start with sample observations, time series or cross-sectional, and adjust them as more information becomes available. As long as the decision maker has less than full confidence in the estimates, considerations similar to Ellsberg's [9] would be appropriate.

Farm Application

The truncated maximin formulation and the truncated minimax constraint formulation in the above are applied to a mixed farm in Hokkaido, Japan. Basic data are adapted from Maruyama and Freund [21, 22]. Seven activities, i.e., Irish potatoes, sugar beets, millet, oats, forage, corn, and milk cows, are introduced. Seven constraints, i.e., land, labor in four busy periods, silage, and feed units, are considered. Other activities and constraints are omitted for simplicity. The associated input-output and restraint coefficients are shown in Table 1.

Beet tops and millet stalks are fed to milk cows as supplements to regular feed crops. The requirement of feed units per milk cow is assumed to be given with certainty. The expected values of these yields (requirements) are shown in Table 2. Variabilities in other input-output or restraint coefficients are not considered for simplicity. Variability in gross margins per unit level of activities, their

Table 1. Input-output and restraint coefficients

Scarce Resources	Irish potatoes	Sugar beets	Millet	Oats	Milk cows	Forage	Corn	Restraints	Unit of resources
Land	1.00	1.00	1.00	1.00		1.00	1.00	7.85	hectares
Labor									
June	52.70	273.43	79.27	10.59	55.51	28.10	49.27	711.30	man-hours
mid-late Aug.	48.88	26.50		292.75	48.28	9.45		480.78	man-hours
early-mid Sept.	124.19		6.15	9.65	37.27	8.05	2.42	471.67	man-hours
late Sept.-early Oct.	58.98		181.30		21.80		219.77	529.23	man-hours
Silage					13.10		−110.88	0	hundred kan*
Feed unit (expected value)		−30.20	−13.40		53.60	−69.88	−59.46	0	hundred units
Unit of activities	hectare	hectare	hectare	hectare	head	hectare	hectare	hectare	

* 1 kan = 3.75 kilograms.

expected values, and a measure of their variability, i.e., $(\bar{c}_i - c_i^{\min})/\bar{c}_i$, where $c_i^{\min}$ denotes the anticipated worst possible value, are shown in Table 3.

Solutions to the truncated maximin formulation are summarized in Table 4. The associated *E-d* efficiency locus is shown in Figure 1. The maximum expected functional value $\bar{E}$ and the corresponding adversity level $\underline{d}$ have proved to be 742,820 and 578,070 *yen*, respectively. The maximin functional value $\bar{d}$ is equal to 582,510 *yen*. As d increases from $\underline{d}$ to $\bar{d}$, the corresponding solutions show (a) a greater degree of diversification among alternative activities and (b) a shift of emphasis from relatively uncertain activities (e.g., milk cows) to relatively safe activities (e.g., potatoes and oats). By these d values and the corresponding u_t values, the probability of ruin, i.e., the probability that the functional value falls short of a preassigned adversity level, can be calculated. Such probabilities associated with the adversity level 582,510 *yen* are shown at the bottom of Table 4. They show a non-increasing tendency with the increase in d as expected.

Since the restraints associated with the feed unit constraints are all equal to zero, the inequalities (11.1) above are modified to account for this fact.

$$(11.2)\quad s_{ti} \leq q, \quad q = \text{param.}, \quad t = 1, \cdots, T, \quad i = 1, \cdots, m.$$

Alternatively, by use of slack variables $w_{ti} \geqq 0$, $t = 1, \cdots, T; i = 1, \cdots, m$,

$$(11.2.2)\quad s_{ti} + w_{ti} = q, \quad t = 1, \cdots, T; \quad i = 1, \cdots, m.$$

Then q is increased from zero to the point where the probability of infeasibility attains unity. In view of the relation, $s_{ti} = q - w_{ti}$, the probability of infeasibility with respect to the feed unit constraints is equal to the sum of y_t's over all t such that $q - w_{ti} > 0$ for some i.

Solutions to the truncated minimax constraint formulation with the adversity level $d = 582{,}510$ *yen* are summarized in Table 5. The associated *E-q* efficiency locus is shown in Figure 2. As q, which can be regarded as a feed unit buffer, increases, the corresponding solutions show (a) a greater degree of specialization in a relatively small number of activities and

Table 2. Yield (requirement) of feed per unit of activities (hundred feed units)

	Irish potatoes	Sugar beets	Millet	Oats	Milk cows	Forage	Corn
1950		−30.76*	−12.96		53.60	−78.81	−64.78
1951		−35.46	−13.46		53.60	−71.07	−56.07
1952		−28.09	−13.07		53.60	−68.87	−69.67
1953		−33.01	−13.05		53.60	−63.80	−50.41
1954		−23.55	−12.48		53.60	−59.10	−50.63
1955		−27.21	−13.31		53.60	−65.59	−60.05
1956		−29.20	−14.02		53.60	−73.25	−52.85
1957		−25.17	−14.01		53.60	−75.85	−71.33
1958		−39.37	−11.29		53.60	−72.57	−59.34

* Negative (positive) figures indicate yields (requirements).

Table 3. Gross margins per unit of activities (thousand 1949 *yen*)

	Irish potatoes	Sugar beets	Millet	Oats	Milk cows	Forage	Corn
1950	144.37	46.20	33.69	28.56	117.32	−5.64	−5.78
1951	125.92	60.03	17.57	19.88	62.81	−6.37	−6.59
1952	108.35	73.15	24.16	20.94	90.82	−6.53	−13.80
1953	102.56	109.14	24.33	33.49	81.33	−5.12	−9.86
1954	132.60	59.51	26.52	22.21	114.17	−5.47	−13.58
1955	99.93	49.97	25.32	21.01	72.09	−6.83	−17.99
1956	95.02	71.76	25.91	26.73	96.35	−5.93	−13.95
1957	149.84	81.03	46.30	24.44	79.87	−4.13	−11.58
1958	123.37	69.84	35.90	20.91	76.37	−7.19	−10.44
Average ($\bar{c}_i$)	120.22	68.98	28.85	24.24	87.90	−5.91	−11.51
$(\bar{c}_i - c_i^{\min})/\bar{c}_i$	.2096	.3302	.3910	.1799	.2854	−.2166	−.5630

Table 4. Solutions to the truncated maximin formulation

Adversity level (d)	0.00	578.07	580.09	582.51	thousand *yen*
Expected value (E)	742.82	742.82	739.08	729.80	thousand *yen*
Irish potatoes	1.38	1.38	1.46	1.63	hectares
Sugar beets	0.24	0.24	0.30	0.42	hectares
Millet	0.00	0.00	0.00	0.00	hectares
Oats	0.00	0.00	0.12	0.17	hectares
Milk cows	6.85	6.85	6.60	6.12	heads
Forage	5.42	5.42	5.20	4.76	hectares
Corn	0.81	0.81	0.78	0.72	hectares
w_1	978.16	400.09	387.75	363.07	thousand *yen*
w_2	578.07	0.00	0.00	0.00	thousand *yen*
w_3	742.30	164.23	156.83	142.42	thousand *yen*
w_4	688.89	110.81	108.52	101.80	thousand *yen*
w_5	938.24	360.16	347.91	324.35	thousand *yen*
w_6	591.77	13.70	9.17	0.00	thousand *yen*
w_7	764.67	186.59	177.14	157.70	thousand *yen*
w_8	741.04	162.96	162.03	159.90	thousand *yen*
w_9	662.29	84.21	81.57	76.39	thousand *yen*
Prob. of ruin with k=582.51	1/9	1/9	1/9	0/9	

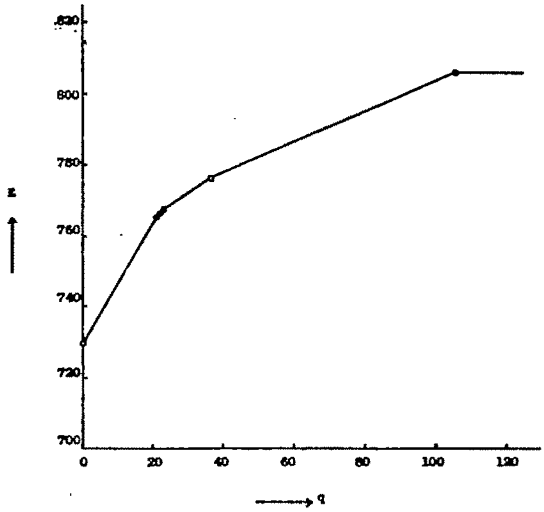

Figure 2. Expectation-feed unit buffer efficiency locus

(b) substitution of a relatively uncertain activity (milk cows) for relatively safe activities (potatoes and oats). The resulting substitution between these activities must be somewhat exaggerated since in this example the feed unit buffer q is assumed to be acquired without any cost and since it is used only by milk cows. The probabilities of infeasibility with respect to feed unit constraints are given at the bottom of Table 5. They show a non-decreasing tendency with the increase in q as expected.

The solution to a problem where all the coefficients are replaced by their expected values, i.e., the "expected value" solution in Madansky's sense [19], is shown for contrast in the final column of Table 5. It naturally shows a greater degree of specialization and associated greater expected gross margins than most of the solutions incorporating uncertainty in the input-output and functional coefficients. The $q-w_{ti}$ values with respect to feed units are estimated, though variability in the yield of feed crops is not taken into consideration in the original "expected value" formulation. Then q is set equal to 64.36, i.e., the smallest of all $q-w_{ti}$ values, and the resulting w_{ti} values are given in the lower part of the column. The probability of infeasibility is estimated as equal to 3/9 which is rather high. This result may suffice to indicate that the "expected value" approach, usually employed in farm planning,

Table 5. Solutions to the truncated minimax constraint formulation with $d=582.51$

Feed buffer (q)	0.00	20.72	21.63	22.84	35.99	105.03	64.36	hundred units
Expected value (E)	729.80	765.09	766.44	767.76	776.05	805.75	788.24	thousand *yen*
Irish potatoes	1.63	1.14	1.12	1.11	1.07	1.06	1.07	hectares
Sugar beets	0.42	0.10	0.09	0.08	0.00	0.00	0.00	hectares
Millet	0.00	0.00	0.00	0.00	0.26	0.47	0.34	hectares
Oats	0.17	0.01	0.00	0.00	0.00	0.00	0.00	hectares
Milk cows	6.12	7.57	7.63	7.67	7.78	7.99	7.87	heads
Forage	4.76	5.71	5.57	5.76	5.60	4.56	5.18	hectares
Corn	0.72	0.89	0.90	0.91	0.92	0.94	0.93	hectares
$w_{1,6}$	107.07	125.90	126.60	126.96	123.58	103.48	115.42	hundred units
$w_{2,6}$	65.91	74.37	74.68	74.82	72.33	60.19	67.39	hundred units
$w_{3,6}$	62.17	73.26	73.67	73.90	72.40	62.81	68.51	hundred units
$w_{4,6}$	26.19	27.56	27.60	27.60	26.28	21.50	24.33	hundred units
$w_{5,6}$	0.00	0.00	0.00	0.00	0.00	0.00	0.00	hundred units
$w_{6,6}$	39.23	45.84	46.08	46.22	45.24	38.88	42.66	hundred units
$w_{7,6}$	71.33	83.33	83.77	83.99	81.73	67.35	75.88	hundred units
$w_{8,6}$	95.45	114.43	115.13	115.53	113.39	96.74	106.53	hundred units
$w_{9,6}$	77.06	86.24	86.57	86.72	83.18	69.10	77.47	hundred units
Probability of infeasibility (Probability ($q-w_{ti}>0$))	0/9	1/9	1/9	1/9	2/9	9/9	3/9	

can give very misleading solutions, and it is important, therefore, to incorporate conceivable uncertainty into the relevant coefficients.

Concluding Remarks

The discrete nature of underlying probability distributions and the simple two-parameter decision criterion, in terms of the expectation and the worst possible outcome, enable the present approach to handle uncertainty in all the coefficients, a_{ij}, b_i, and c_j, in a symmetrical manner. Furthermore, it generates associated information such as the probabilities of ruin and infeasibility which should be of significant use in evaluating alternative farm plans. In general, the average farmer can grasp such probabilities as measures of uncertainty more easily than he can the more conventional measures of uncertainty, e.g., standard deviations or variances of gross margins.

The formal simplicity of the present approach makes available an economy of information through a more direct utilization of the basic informational inputs in particular, as compared with risk programming where firsthand information about the functional coefficients, for example, must be transformed into expectations, variances, and covariances in advance of the analysis. This economy of information may be significant in many practical applications where the amount of information is severely limited. To be definite, a plausible set of values, say 5, 40, and 60 for T, m, and n, respectively, is assumed. Then, the present model makes a full use of 12,000 a_{tij}'s, 200 b_{ti}'s, and 300 c_{tj}'s, while the risk programming model requires 3,660 expectations, variances, and covariances out of 300 c_{tj}'s, a tremendous strain on the basic informational inputs. It sparingly uses only one-fifth of the 12,000 a_{tij}'s and 200 b_{ti}'s (i.e., 2,400 $\bar{a}_{ij}$'s and 40 $\bar{b}_i$'s).

Closely connected with the above economy is an economy of computation provided by the present model. Should one work with the truncated maximin problem above, suppressing uncertainty in the input-output and restraint coefficients to make the problem comparable with the regular risk programming problem, and solve the corresponding risk programming problem by means of the modified simplex method [6, 7], the dimension of simplex tableau for the present model will be 45×60. That for the risk program will be 100×100, assuming for T, m, and n the same set of values in the above. In both cases the slack columns are not included in the count of tableau columns. Furthermore, the present model requires only a linear programming computer code with parametric option which is more readily available than a quadratic programming code required by the risk programming model.

If the minimax constraint problem is worked with and the corresponding discrete stochastic programming problem is solved by Cocks' method [5], while taking into account uncertainty in the restraint coefficients, the dimension of simplex tableau for the present model will be 205×60; that for the Cocks model will be 12,205×12,305. Again, slack columns are not included in the count of tableau columns. The present model generates series of solutions disclosing the possible trade-offs between the expected functional value and the worst possible functional value and between the probability of infeasibility and other measures of uncertainty, while the latter provides only a single solution that maximizes the expected functional value. The truncated minimax constraint formulation tends to require a much greater number of constraints than variables. Dualization of the problem will reduce the computational cost in light of the fact that the computational cost of a linear program with m constraints and n variables is proportional to m^2n, as pointed out by Madansky [19].

The dimension of the simplex tableau will be 205×260 for the corresponding truncated maximin problem in the "slack" solution formulation. This model generates a series of solutions disclosing the possible trade-offs between the expected functional value and the worst possible functional value, between the probability of ruin and the probability of infeasibility. Both the expected and the worst possible functional values take into account costs of shortages. As for computational costs, this model requires only a single parametric run, whereas the minimax constraint model usually requires a great number of parametric runs to explore the whole range of trade-offs. This model requires more columns than does the minimax constraint model. However, a majority ($Tm=200$) of them are "slack" columns (in Madansky's sense) which as a whole constitute a negative identity matrix of order Tm ($=200$). This property of the tableau should help reduce computational costs in many practical applications.

Several of these desirable features are not

without some costs. They are based on the assumed discrete nature of underlying probability distributions and the simple two-parameter decision criterion in terms of the expectation and the most adverse outcome. The discrete probability distribution may not be very restrictive in many practical contexts where severely limited information is the rule. As pointed out [9, 20], a certain discontinuity implied by the above decision criterion prevents it from satisfying the expected utility axiom. Though the discontinuity in the decision criterion itself is by no means objectionable, it deprives the present approach of an access to many useful results based on the expected utility hypothesis.

References

[1] BAUMOL, WILLIAM J., "An Expected Gain-Confidence Limit Criterion for Portfolio Section," *Mgt. Sci.* 10:174–182, Oct. 1963.

[2] CHARNES, A., "Constrained Games and Linear Programming," *Proc. Nat. Acad. Sci.* 39:639–641, July 15, 1953.

[3] ———, AND W. W. COOPER, "Chance-Constrained Programming," *Mgt. Sci.* 6:70–79, 1959.

[4] ———, ———, AND G. L. THOMPSON, "Constrained Generalized Medians and Hypermedians as Deterministic Equivalents for Two-Stage Linear Programs Under Uncertainty," *Mgt. Sci.* 12:83–112, Sept. 1965.

[5] COCKS, K. D., "Discrete Stochastic Programming," *Mgt. Sci.* 15:72–79, Sept. 1968.

[6] CUTLER, L., "Fortran 4 Quadratic Programming Code," SHARE General Program Library, No. 3326, 1965.

[7] DANTZIG, G. B., *Linear Programming and Extensions*, Princeton, Princeton University Press, 1963, Ch. 24.

[8] EL AGIZY, M., "Two-Stage Programming Under Uncertainty with Discrete Distribution Function," *Oper. Res.* 15:55–70, 1967.

[9] ELLSBERG, DANIEL, "Risk, Ambiguity, and the Savage Axioms," *Quart. J. Econ.* 75:643–669, Nov. 1961.

[10] EVERS, WILLIAM H., "A New Model for Stochastic Linear Programming," *Mgt. Sci.* 13:680–693, May 1967.

[11] HANF, E., "Development of a Decision Rule for Farm Planning Under Uncertain Conditions," in *Policies, Planning and Management for Agricultural Development*, Papers and Reports of the 14th Internation Conference of Agricultural Economists, Oxford, Institute of Agrarian Affairs for International Association of Agricultural Economists, 1971, pp. 325–338.

[12] HAZELL, P. B. R., "Game Theory—An Extension of Its Application To Farm Planning Under Uncertainty," *J. Agr. Econ.* 21:239–252, 1970.

[13] ———, AND R. B. HOW, "Obtaining Acceptable Farm Plans Under Uncertainty," in *Policies, Planning and Management for Agricultural Development*, Papers and reports of the 14th Internation Conference of Agricultural Economists, 1971, pp. 338–347.

[14] HEADY, EARL O., AND WILFRED CANDLER, *Linear Programming Methods*, Ames, Iowa State College Press, 1958, Ch. 17.

[15] IMAMURA, Y., "Game Theoretic Programming," *Bull. Nat. Inst. Agr. Sci., Tokyo*, Series H, No. 36, Dec. 1966.

[16] KATAOKA, SHINJI, "A Stochastic Programming Model," *Econometrica* 31:181–196, Jan.–April, 1963.

[17] KAWAGUCHI, T., AND Y. MARUYAMA, "An Approach to the Variability in Functional Coefficients in Linear Programming," *J. Rural Econ.* 41:145–155, 1970.

[18] LUCE, R. DUNCAN, AND HOWARD RAIFFA, *Games and Decisions*, New York, John Wiley & Sons, Inc., 1957.

[19] MADANSKY, A., "Methods of Solution of Linear Programs Under Uncertainty," *Oper. Res.* 10:463–471, 1962.

[20] MARKOWITZ, HARRY MAX, *Portfolio Selection*, New York, John Wiley & Sons, Inc., 1959.

[21] MARUYAMA, Y., AND R. J. FREUND, "Effects of Uncertainty on Farm Production—An Approach by Means of Parametric Nonlinear Programming," *J. Rural Econ.* 37:154–159, 1966.

[22] ———, "Prediction, Uncertainty and Production Planning—A Combined Use of Statistical Techniques and Nonlinear Programming," *J. Rural Econ.* 39:1–12, 1967.

[23] MARUYAMA, Y., AND T. KAWAGUCHI, "An Approach to Farm Planning Under 'Ambiguity,'" in *Policies, Planning and Management for Agricultural Development*, Papers and reports of the 14th Internation Conference of Agricultural Economists, 1971, pp. 347–355.

[24] ———, "A Generalization of the Equivalence Between Constrained Games and Linear Programming," Dept. of Agr. Econ., Kyoto Univ., Sept. 1971, mimeo.

[25] ———, "Constrained Games in Farm Planning," Dept. of Agr. Econ., Kyoto Univ., Oct. 1971, mimeo.

[26] MCINERNEY, J. P., "Maximin Programming—An Approach to Farm Planning Under Uncertainty," *J. Agr. Econ.* 18:279–289, 1967.

[27] ———, "Linear Programming and Game Theory Models—Some Extensions," *J. Agr. Econ.* 20:269–278, 1969.

[28] RAIKE, WILLIAM M., "Dissection Methods for Solutions in Chance Constrained Programming Problems Under Discrete Distributions," *Mgt. Sci.* 16:708–715, July 1970.

[29] ROY, A. D., "Safety First and the Holding of Assets," *Econometrica* 20:431–449, July 1952.

[30] SENGUPTA, J. K., AND J. H. PORTILLO-CAMPBELL, "A Fractile Approach to Linear Programming Under Risk," *Mgt. Sci.* 16:298–308, Jan. 1970.

[31] TELSER, LESTER G., "Safety First and Hedging," *Rev. Econ. Stud.* 23:1–16, 1955.

[32] TINTNER, GERHARD, "A Note on Stochastic Linear Programming," *Econometrica* 28:490–495, April 1960.

[33] VAN MOESEKE, PAUL, "Minimax-Maximax Solution to Linear Programming Under Risk" (Abst.), *Econometrica* 31:749–750, Oct. 1965.

Modified Price, Production, and Income Impacts of Food Aid Under Market Differentiated Distribution*

KEITH D. ROGERS, UMA K. SRIVASTAVA, AND EARL O. HEADY

Estimation of negative production impacts of food aid rests heavily on measurement of resulting price changes. Previous studies have assumed an exogenous shift in supply resulting from distribution of the imported commodities but have ignored the income effect on demand. Distribution of food aid commodities to consumers at concessional prices provides an increase in real income and corresponding shift in demand for food. The shift in demand compensates for part of the exogenous shift in supply, reducing the potential impact on domestic prices. Based on market differentiation, the production impact in India is estimated at one tenth of previous estimates.

FOOD aid financed under P.L. 480 has helped to bridge the food gap in recipient countries for a decade and a half. For countries in early developmental stages, it has helped meet expanded consumer demand. As Witt and Eicher [18] indicate, it has helped avoid alternative measures such as (a) higher prices and/or rationing to adjust use to existing food supplies, or (b) use of more foreign exchange for purchase of imported foods.

Serious questions have been raised, however, about potential negative impacts of food aid on recipient countries. Schultz [16] expressed apprehension about price disincentive effects of food aid on agricultural production in recipient countries. Others disagreed with him by either (a) denial of production responsiveness to price changes in developing countries, which rules out any disincentive effects [3, 8, 14], or (b) acceptance of production responsiveness but disagreement on the degree of such response. Fisher argues that Schultz and others have overstated the negative price effects of food aid by implicitly assuming (a) that the elasticity of domestic supply is zero and (b) a single market for imported and domestic commodities so that distribution of concessional imports substitutes directly for domestic demand [5]. In the face of increasing evidence to the contrary, the proposition that production in developing countries is not price responsive has little basis [1, 2, 3, 4, 9, 10]. On the second count, there is evidence that markets for domestically produced commodities and for the same commodity supplied through imports are not perfectly homogeneous; hence, demand for domestic commodities is not directly substituted by imported foodgrains, particularly in India, which Schultz used as an illustration. Finally, Fisher argues that the negative impact of food aid can be reduced if it is distributed outside the market for domestic production so that distribution creates additional demand [5].

Estimation of negative production impacts resulting from surplus commodity distribution thus rests heavily on measurement of price changes and related production response. Only a few quantitative studies have been made to test the hypothesis put forth by Schultz. One such study by Mann [11] used an econometric model to test the price and production effects of P.L. 480 impacts on the Indian economy. Although his model confirmed a negative impact of food aid on prices and agricultural production in India, it contained only one demand equation. He implicitly assumed P.L. 480 import demand to be homogeneous with demand for domestic commodities and that P.L. 480 commodities enter the market in the same way as domestically produced commodities. However, as pointed out elsewhere [6, 12, 15, 17] P.L. 480 commodities enter the market in many countries through a concessional market. As will be discussed later in this paper, there is strong evidence that the distribution of food aid commodities through a concessional market provides for market differentiation and, in turn, expanded demand as a result of a real income effect of lower prices in the concessional market as compared to open market.

The availability of food to some consumers at a lower price represents an increase in real income to consumers in the aggregate and

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KEITH D. ROGERS *is research associate,* UMA K. SRIVASTAVA *is post-doctoral research associate, and* EARL O. HEADY *is Curtiss distinguished professor of economics and executive director of the Center for Agricultural and Rural Development at Iowa State University.*

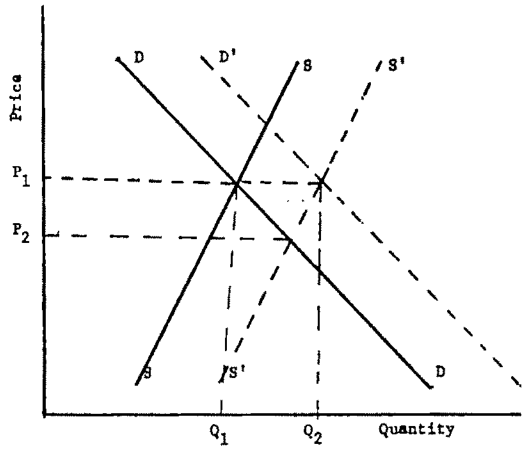

Figure 1. Aggregate food supply and demand equilibrium

implies a shift in the aggregate demand curve. In Figure 1, for example, P.L. 480 imports equal to Q_1Q_2 would depress prices from P_1 to P_2 without a demand shift. However, if demand shifts from D to D′, due to the income effects of food aid, price is not depressed. This is a possibility that should be examined. Mann's study, in overlooking the presence of a differentiated market, overstated the negative price and production effect of food aid. For the same reasons, it likely underestimated the positive contribution of the aid.

Objectives, Data, and Framework

The objective of this paper is to develop a theoretical model to test Fisher's hypothesis; namely, that the negative effect of food aid on prices and production is much less (or could be absent) under a differentiated market situation. If Fisher's theoretical argument can be supported empirically, previous analytical work, which neglected the real income effect on demand, promises to have overestimated the negative impact of P.L. 480.

The data used in the analysis relate to India for 1956–67, but the framework is of wider interest because it can be used both to make improved estimates of the impact of aid on recipient countries which do have a differentiated market situation and as a guide for administering food aid to minimize negative price and production effects in recipient countries while maximizing beneficial effects.

The concept of market differentiation is incorporated into Mann's analytical framework by including an additional equation so that the system provides for cereal purchases on both the open market and the concessional market at lower prices. Incorporating a second "demand" equation and modifying various other equations in the basic Mann model brings stronger causal relationships and improves their reliability. The model is specified by defining several *a priori* functional relationships that are presumed to exist as indicated by economic theory.

Model for Analyzing P.L. 480 Impact Under Market Differentiation

The model includes a supply equation, an open market demand equation, a concessional market distribution equation,[1] an income equation, a commercial import equation, a withdrawal from stocks equation, and an excess demand equation. The reduced form of the system of seven equations provides estimates for the quantitative impact of P.L. 480 shipments of cereals distributed through a concessional market arrangement. Specification of these relationships is explained below.

Supply of cereals in the current period

The quantity available for consumption from domestic production in a particular year is primarily the result of production decisions, weather conditions, and available technology before and during the growing season. Supply from the domestic sources in period t is a function of production during the agricultural year $t-1$ (1970–71, July–June), and production, in turn, has been found to be a function of price in the preceding agricultural year (say, 1969–70).

[1] The concessional distribution equation represents demand under fixed price and controlled supply conditions, consequently, designated distribution rather than demand.

In developing countries which lack an effective market forecasting system, the cultivators' primary source of information is prices received for the previous crop. Thus, supply becomes a function of prices in period $t-2$. Rainfall in period $t-1$ (R_{t-1}) and cereal yield (T_{t-1}), as a proxy for technology, have a direct impact on production. T_{t-1} and R_{t-1} are used to account for the contribution of both factors to production.[2] The theoretical supply function thus is specified as

$$(1) \qquad Q_t^s = f_1(P^o{}_{t-2}, R_{t-1}, T_{t-1})$$

where

Q_t^s = per capita quantity of cereals available from domestic production for consumption in period t,

$P^o{}_{t-2}$ = a deflated index of wholesale prices of cereals in the period before production,

R_{t-1} = a rainfall index as a proxy for weather conditions during the producing season, and

T_{t-1} = cereal yield as a proxy for other factors affecting adoption of technology.

Open market demand for cereal

Economic theory states that quantity demanded per capita is a function of the price of the commodity itself, the price of related commodities, and income level. Thus, the open market demand equation is specified as:

$$(2) \qquad Q_t^d = f_2(P_t^o, P_t^r, Y_t)$$

where

Q_t^d = per capita quantity of cereals demanded in the open market for consumption in period t,

P_t^o = the index of deflated wholesale prices of cereal in the period t,[3]

P_t^r = the deflated price of noncereal foods in period t, and

Y_t = deflated per capita consumer income in period t.

Distribution from the concessional market

Distribution of P.L. 480 imports through the concessional market is a function of economic variables at the minimum level and, because of the fixed price offering, physical restraint at the upper level. Some consumers consider imported cereals an inferior commodity and continue to purchase cereals in the open market even when there is some price differential between open and concessional markets. As the two prices diverge, however, more and more consumers are willing to substitute imported cereals for domestic cereals. Consequently, the demand for cereals through the concessional market is a function of price at the concessional market itself, price of substitute cereals in the open market, and the income level of consumers. At the upper limit, price adjustment cannot serve as a balancing mechanism to equate demand with a limited supply because the price is fixed by the government and has been held relatively constant. Consequently, the upper limit on distribution through the fair price shops is the quantity that the government chooses to release for distribution. Since the primary source of commodities for distribution through the fair price shops has been P.L. 480 imports, the quantity of imports is entered in the concessional distribution equation as a proxy for the maximum quantity available for distribution.[4] The concessional distribution equation is specified as

$$(3) \qquad Q_t^c = f_3(P_t^p, P_t^o, Y_t, M_t^p)$$

where

Q_t^c = per capita quantity of cereals distributed through the concessional market in period t,

P_t^p = predetermined cereals price charged in the concessional market (deflated by a consumer price index) in period t,

[2] Although rainfall and yield would appear to create a problem of multicollinearity, the basic data indicate that the correlation between the two variables is only 0.10.

[3] Strictly speaking, the supply equation is formulated in terms of wholesale prices and the demand equation in terms of retail prices. But with an assumption about constant marketing margins, a demand function can be derived in terms of wholesale prices.

[4] M_t^p (per capita P.L. 480 imports in Kgs) and d_t^p (per capita issues from fair price shops in Kgs) are as follows for the years 1956–1967:

		1956	1957	1958	1959	1960	1961	1962	1963	1964	1965	1966	1967
M_t^p		5.23	6.70	4.85	7.53	10.03	5.27	6.37	8.60	10.73	12.46	16.81	12.23
d_t^p		0.39	7.52	9.61	12.19	11.40	8.99	9.64	11.17	18.24	20.70	28.22	25.76
M_t^p/d_t^p	100	7.45	89.09	50.47	61.77	87.89	58.17	66.07	76.99	58.66	60.19	59.60	47.47

Excluding 1956 (when P.L. 480 imports were very small), the correlation of these two series is 0.9219.

M_t^p = per capita quantity of concessional imports of cereal under P.L. 480 in period t.

Income

The economy usually is dominated by the agricultural sector in developing countries. Hence, agricultural output constitutes a very large portion of national income, and fluctuations in this output have a significant impact on aggregate income. The sector that is second in importance in the Indian economy is industry. The third major income source in India is government expenditure, particularly through the involvement of the government in financing development investments. Thus, the income equation is specified as

$$(4) \qquad Y_t = f_4(Q_t^s, Q_t^i, G_t)$$

where

Q_t^i = the value of per capita industrial output (deflated by the consumer price index),

G_t = deflated per capita government expenditure in period t.

Commercial imports

Commercial imports of cereals in India serve as a government policy investment to relieve inflationary pressure on food prices when and where domestic food shortages occur. In this role, the government imports food to satisfy consumer demand, and commercial import of cereals are effectively a function of the same factors that determine the demand for cereals in the open market. The commercial import equation is specified as

$$(5) \qquad M_t^o = f_5(P_t^o, P_t^r, Y_t)$$

where

M_t^o = per capita quantity of commercial import of cereals in period t.

Withdrawal from government stocks

Withdrawal from government stock provides a residual source of cereals to balance other government programs. As the government increases internal procurement of domestic cereals to support prices, the need for net withdrawals to control inflation of cereal prices and to satisfy other government demand (such as feeding military personnel and inhabitants of public institutions) decreases. In the opposite direction, as the government increases the availability of cereals for distribution through the concessional market, withdrawals from government stocks must increase if other sources of supply remain constant. Finally, commercial and concessional imports are alternative sources for satisfying government demand for various programs so that withdrawals from the government stock are a function of the level of import activities. The withdrawal equation is defined as

$$(6) \qquad W_t = f_6(Q_t^c, M_t^o, M_t^p, C_t^p)$$

where

W_t = per capita net withdrawals of cereals from government stocks in period t,

C_t^p = per capita internal procurement of cereals by the government in period t.

Market clearing

The last equation is a market identity equation to close the system by forcing excess demand for cereals to be equal to zero and is specified as

$$(7) \quad Q_t^d + Q_t^c - Q_t^s - M_t^p - M_t^o - W_t = 0.$$

The model consists of seven equations and 16 variables. Since the purpose of this model is to evaluate the economic impact of P.L. 480 imports on prices and domestic supply of cereals, certain variables are treated as predetermined or given outside the system. The predetermined or exogenous variables include T_{t-1}, R_{t-1}, P_t^r, P_t^p, C_t^p, M_t^p, G_t, $P^o{}_{t-1}$, and Q_t^i. The values for these variables are given at a particular point in time and are not subject to determination by the econometric model. Seven variables, including Q_t^s, Q_t^d, Q_t^c, P_t^o, Y_t, M_t^o, and W_t, are classified as endogenous.

Empirical Results

The seven structural equations provide the joint interactions of the variables in the system. To provide for independent examination and analysis of the jointly determined variables, the system is solved to obtain the reduced form in which each endogenous variable is uniquely defined as a function of the exogenous variables and the constraints of the system in the derived reduced form.

Equations 2 through 6 are overidentified [7]. Under conditions of overidentification, the two stage least squares method of regression provides consistent estimates of coefficients of the structural form. With estimates of the coeffi-

cients for the endogenous variables (β's) and the predetermined variables (Γ's), the reduced form coefficients can be derived as

$$\hat{\pi} = \hat{\beta}^{-1}\hat{\Gamma} \tag{8}$$

where

$\hat{\pi}$ = the matrix of estimated reduced form coefficients,
$\hat{\beta}$ = the matrix of estimated coefficients of endogenous variables, and
$\hat{\Gamma}$ = the matrix of estimated coefficients of predetermined variables.

The structural equations of models have been estimated by using data from the Indian economy during 1956–67 and collected from a number of published sources. Except for equation (1), two stage least squares method was used to estimate coefficients for the structural equations. Because equation (1) contains no endogenous variables as independent variables, ordinary least squares were used to estimate the associated coefficients. The estimated coefficients for the structural equations are presented in Table 1. The variables are as defined earlier. Signs of nearly all coefficients for the estimated equations agree with economic theory.

The supply equation has positive signs for all three independent variables, indicating that the supply of cereals (Q_t^s) reacts positively to increases in the weather variables (R_{t-1}), the proxy for technology (T_{t-1}), and price (P^o_{t-2}). The estimated price elasticity of supply at the mean is 0.156, which compares with National Council of Applied Economic Research estimates of 0.22 for rice, 0.16 for wheat, and 0.16 for barley [13].

The open market demand equation has signs on all coefficients that agree with economic theory, indicating that demand for cereals (Q_t^d) is positively correlated with price of other food (P_t^r) and changes in income (Y_t).[5] The estimated price elasticity of demand is -0.39, slightly higher than the National Council's estimate of -0.34.

The concessional market distribution equation indicates that Q_t^c is positively correlated with the price of cereals in the open market (P_t^o) and negatively correlated with income level (Y_t) and the price of cereals at the fair price shops (P_t^p).[6] The relatively large coefficient on M_t^p supports the arguments that distribution through the concessional market is highly correlated with imports under P.L. 480 and associated decisions to make these commodities available for distribution through the fair price shops.

The income equation indicates that an increase in (Y_t) is positively correlated with agricultural (Q_t^s) and industrial supply (Q_t^i) but negatively correlated with government expenditure (G_t). The sign on government expenditure is not in conformity with the logic of economic theory. In examining the correlation matrix (Table 2) for the variables in the equation, it was noted that government expenditure has been positively correlated with both aggregate income and per capita income but negatively correlated with the deflated or

Table 1. Two stage least squares estimates of structural equations

Equation number	Estimated equation
1[a]	$Q_t^s = -13.89343 + \underset{(0.02665)}{0.09118}\, T_{t-1} + \underset{(0.12615)}{0.56808}\, R_{t-1} + \underset{(0.31964)}{0.24424}\, P^o_{t-2}$
2	$Q_t^d = -10.54661 - \underset{(0.34411)}{0.553321}\, P_t^c + \underset{(0.14954)}{0.72847}\, Y_t + \underset{(0.28149)}{0.047698}\, P_t^r$
3	$Q_t^c = 60.91986 + \underset{(0.23572)}{0.209881}\, P_t^c - \underset{(0.09075)}{0.251656}\, Y_t - \underset{(0.14373)}{0.22217}\, P_t^p + \underset{(0.389855)}{0.89376}\, M_t^p$
4	$Y_t = 118{,}91530 + \underset{(0.39448)}{0.80042}\, Q_t^s + \underset{(0.25924)}{0.28386}\, Q_t^i - \underset{(0.00089)}{0.00092}\, G_t$
5	$M_t^e = 27.84666 + \underset{(0.10881)}{0.09045}\, P_t^c - \underset{(0.04729)}{0.14608}\, Y_t + \underset{(0.08901)}{0.03172}\, P_t^r$
6	$W_t = 1.52758 + \underset{(0.17889)}{0.97393}\, Q_t^c - \underset{(0.39028)}{0.53602}\, M_t^e - \underset{(0.47693)}{1.62118}\, C_t^p - \underset{(0.22458)}{0.89938}\, M_t^p$

Asymptotic standard errors are given in parentheses below the estimated coefficients.

[a] Coefficients estimated by ordinary least squares.

[5] An alternative formulation of the open market demand equation was considered which included the price charged at the fair price shops, but the regression coefficient was insignificant even at low levels. Consequently, the concessional price was excluded from the final equation.

[6] An alternative formulation of the concessional distribution equation included price of other food, but the regression coefficient was insignificant even at low levels and caused the ratio of regression sum of squares to residual sum of squares to decrease.

Table 2. Correlation coefficients for government expenditure and income

	Government expenditure	Deflated government expenditure
Aggregate income	0.9625	0.7633
Per capita income	0.9515	0.7483
Deflated per capita income	−0.5568	−0.2228

real income. If the sign is opposite for per capita income and per capita income divided by price, price level must be increasing faster than per capita income to make real per capita income decline. This is interpreted to mean that although government expenditure has caused an increase in money incomes, it has also caused prices to rise enough to force up the consumer price index faster than money income with a negative impact on real income for the period under study.

The commercial import equation indicates that imports vary inversely with per capita income level (Y_t) and directly with prices of cereals (P_t^c) and other food (P_t^r).[7] This further supports the contention that imported cereals are substitutes for domestic food and not complements. The stock equation indicates that withdrawals (W_t) are directly related to distribution through the fair price shops (Q_t^c) and inversely related to commercial imports (M_t^c), internal procurement (C_t^p), and P.L. 480 imports (M_t^p).[8]

The estimated reduced form coefficients (Table 3) of particular interest to this study are those associated with variable M_t^p or P.L. 480 imports. The coefficients or impact multipliers from the reduced form model indicate that increasing P.L. 480 imports by one kilogram per capita depresses cereal prices by 0.1314 unit ($\hat{\pi}_{47}$) of the price index, increases demand by 0.0727 kilogram per capita ($\hat{\pi}_{27}$), and increases concessional distribution by 0.8557 kilogram per capita ($\hat{\pi}_{37}$).[9] Consequently, 92.84 percent of the increase in P.L. 480 imports would result in increased consumption. As an example, data indicate that P.L. 480 imports for 1967 (4.055 million metric tons) increased consumption by 3.771 million metric tons or about 7.38 kilograms per capita for the year. Associated with a one kilogram per capita increase in P.L. 480 imports was a 0.0119 kilogram ($\hat{\pi}_{67}$) decrease in commercial imports and a 0.0597 kilogram ($\hat{\pi}_{77}$) withdrawal from government stocks. Due to the time lag in supply response, supply is unaffected in period t.

To measure the price impact in succeeding years, it is necessary to use a delay multiplier that equals $\hat{\pi}_{47}\hat{\pi}_{49}{}^{\frac{1}{2}P}$, where $P=0, 2, 4 \cdots$, because of a two-year lag between P_t^c and P^c_{t-2} [11]. Therefore, the delay multiplier for cereal price is 0.020039 in the second year, −0.003056 in the fourth year, and 0.000466 in the sixth year. The first delay multiplier represents a change of less than three hundredths of 1 percent, using the mean values of the price index, and the multiplier values in the succeeding years are essentially zero.

The impact on supply (Table 4) is measured by the delay multiplier $\hat{\pi}_{19}\hat{\pi}_{47}\hat{\pi}_{49}{}^{\frac{1}{2}P-1}$, where $P=2, 4, 6 \cdots$, because of the time lag of price impact on production [11]. Evaluated at $P=2$ to measure the impact of a change in price during the period when P.L. 480 imports occur upon production two years later, the delay

[7] Alternative forms of the impact equation were considered which included concessional imports and the ratio of cereal prices to other food prices, but regression coefficients for both were insignificant even at low levels.

[8] Alternative forms of the withdrawal equation were considered which included consumer demand factors such as prices of cereals and other food and income levels, but none of the regressions of this nature produced ratios of regression to residual sum of squares which exceeded 1.0, and consequently were insignificant.

[9] The mean population of India for the period under consideration was 450.48 million, so that imports of one kilogram per capita involves 450,480 metric tons of cereal.

Table 3. Estimated reduced form coefficients to measure impact of P.L. 480 imports on the Indian economy, 1956–67

	Intercept	T_{t-1}	R_{t-1}	P_t^r	P_t^p	C_t^p	M_t^p	G_t	P^c_{t-2}	Q_t^i
Q_t^s	−13.8934	0.0912	0.5681	0.0	0.0	0.0	0.0	0.0	0.2442	0.0
Q_t^d	−5.9595	0.0847	0.5275	0.0168	0.0054	−1.5250	0.0727	0.0	0.2268	−0.0043
Q_t^c	7.2528	−0.0349	−0.2173	0.0162	−0.2250	0.7989	0.8557	−0.0001	−0.0934	0.0391
P_t^c	133.6264	−0.0569	−0.3547	0.5578	−0.0098	2.7561	−0.1314	−0.0012	−0.1525	0.3815
Y_t	107.7947	0.0730	0.4547	0.0	0.0	0.0	0.0	−0.0009	0.1955	0.2839
M_t^c	24.1866	−0.0158	−0.0985	−0.0368	−0.0009	0.2493	−0.0119	0.0	−0.0424	−0.0070
W_t	56.2758	−0.0256	−0.1593	−0.0038	−0.2189	−0.9754	−0.0597	−0.0001	−0.0685	0.0418

Table 4. Total effect of P.L. 480 imports on domestic production in India

Year	Delay multipliers	Cumulated multipliers
2	−0.032088	−0.032088
4	0.004893	−0.027195
6	−0.000746	−0.027941
8	0.000114	−0.027827
10	−0.000017	−0.027844
12	0.000003	−0.027841
14	—	−0.027841

multiplier is −0.032088. In other words, each ton per capita of cereals supplied through P.L. 480 to India depresses the domestic supply by 0.032088 ton per capita during the production season two years later. Similarly, at $P=4$ the multiplier is 0.004893 so that the impact of one ton of P.L. 480 cereals results in 0.004893 ton per capita of increased cereal production. At $P=6$, the multiplier is again negative at −0.000746. In quantity terms at the mean population of India for the period under consideration, P.L. 480 imports of one kilogram per capita (450,480 metric tons) of cereals are estimated to have depressed domestic production by 14,445 metric tons two years later, increased production by 2,204 metric tons four years later, and depressed production by 336 metric tons six years later.

The net impact on supply is most accurately measured by the cumulated multipliers over several years. Each kilogram of P.L. 480 cereals is estimated to have depressed production of cereals by 0.027841 kilogram so that for each 450,480 metric tons of imports production was depressed by 12,600 metric tons over a 14-year period, with the major impact coming as a result of the first and second round of price changes. Comparing the authors' estimated multipliers with Mann's (Fig. 2), the cumulative impact of distribution through a differentiated market is about one tenth the impact with a nondifferentiated market.

Summary

The model developed and evaluated in this paper differs uniquely from previous attempts to evaluate the impact of P.L. 480 imports on recipient economies. It explicitly incorporates variables to account for the case where P.L. 480 imports are distributed to consumers in a manner such that there is a shift in demand as well as a shift in total supply.[10] With the shift in demand as well as supply allowed, the impact of P.L. 480 on domestic supply is estimated to be less than 9 percent of the magnitude estimated by Mann [11], who assumed only a shift in supply. In contrast to a reduction in domestic supply of 143,200 metric tons as estimated by Mann, the revised cumulated multiplier derived in the current study implies a negative impact of only 12,600 metric tons on domestic supply over a 14-year period.

For policy formulation and application, the conclusion of this analysis indicates that the negative impact of P.L. 480 on domestic prices

[10] For a price elasticity of demand of −0.39 a decrease in price of 0.1314 implies a change in quantity demanded of 0.07227 kilogram per capita if adjustments were made along the demand curve as compared to the actual increase of 0.9284 kilogram per capita implying a shift in demand.

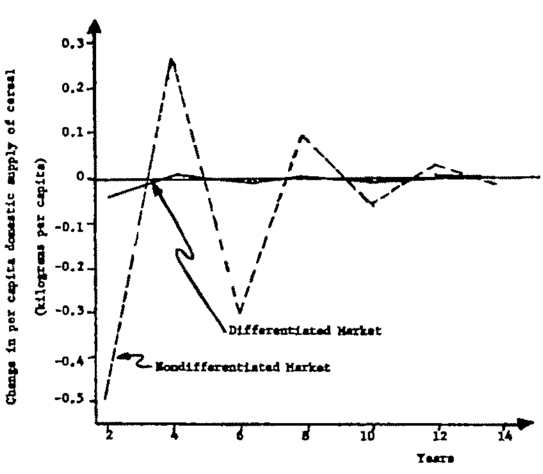

Figure 2. Multiperiod production impact of distributing P.L. 480 cereal (one kilogram per capita) under alternative market conditions

and supply can be significantly reduced if the commodities are distributed in the recipient economy in a way that creates new demand rather than substituting or competing with the existing demand. The analysis indicates that distribution through fair price shops in India has provided for increased consumption amounting to 93 percent of the amount imported. Since fair price shop distribution is at a lower price than the open market price, distribution through these shops has increased consumer welfare by increasing consumption and lowering price. At the same time, the distribution of P.L. 480 commodities has depressed domestic prices in the open market by only two hundredths of 1 percent. Thus, the analysis supports Fisher's theoretical hypothesis that distribution under a differentiated market situation will minimize price and production impacts of food aid and implies that previous studies have underestimated the net contribution of food aid to domestic supply because the income effect of distributing food aid at concessional prices has been ignored.

References

[1] BATEMAN, MERRILL J., "Aggregate and Regional Supply Functions for Ghanian Cocoa, 1946–1962," *J. Farm Econ.* 47:384–401, May 1965.

[2] BEHRMAN, JERE R., "Supply Response in Underdeveloped Agriculture: A Case Study of the Four Major Annual Crops in Thailand, 1937–63," unpublished Ph.D. thesis, Massachusetts Institute of Technology, 1966.

[3] DANTWALA, M. L., "Incentives and Disincentives in Indian Agriculture," *Indian J. Agr. Econ.* 22:1–25, April–June 1967.

[4] DEAN, EDWIN R., "Economic Analysis and African Responses to Prices," *J. Farm Econ.* 47:402–409, May 1965.

[5] FISHER, FRANKLIN M., "A Theoretical Analysis of the Impact of Food Surplus Disposal on Agricultural Production in Recipient Countries," *J. Farm Econ.* 45:863–875, Nov. 1963.

[6] India, Government of, Department of Food, "Report of the Study Team on Fair Price Shops," New Delhi, India, 1966.

[7] JOHNSTON, J., *Econometric Methods*, New York, McGraw-Hill Book Company, 1960.

[8] KHATKHATE, DEENA R., "Some Notes on the Real Effects of Foreign Surplus Disposal in Underdeveloped Economies," *Quart. J. Econ.* 76:186–196, May 1962.

[9] KHUSRO, ALI M., "The Pricing of Food in India," *Quart. J. Econ.* 81:271–285, May 1967.

[10] KRISHNA, RAJ, "Farm Supply Response in India-Pakistan: A Case Study of the Punjab Region," *Econ. J.* 73:477–487, Sept. 1963.

[11] MANN, JITENDAR S., "The Impact of Public Law 480 Imports on Prices and Domestic Supply of Cereals in India" (Part I), *J. Farm Econ.* 49:131–146, Feb. 1967.

[12] ———, "The Impact of Public Law 480 Imports on Prices and Domestic Supply of Cereals in India: Reply," *Am. J. Agr. Econ.* 50:145–147, Feb. 1968.

[13] National Council of Applied Economic Research, "Long Term Projections of Demand and Supply of Selected Agricultural Commodities—1960–1961 to 1975–76," New Delhi, India, 1962.

[14] OLSON, R. O., "Discussion: Impact and Implications of Foreign Surplus Disposal on Underdeveloped Economies," *J. Farm Econ.* 42:1042–1045, Dec. 1960.

[15] RATH, NILKHATH, AND V. S. PATVARDHAN, *Impact of Assistance Under P.L. 480 on Indian Economy*, New York, Asia Publishing House, 1967.

[16] SCHULTZ, T. W., "Value of U. S. Farm Surpluses to Underdeveloped Countries," *J. Farm Econ.* 42:1019–1030, Dec. 1960.

[17] SRIVASTAVA, UMA K., "The Impact of Public Law 480 Imports on Prices and Domestic Supply of Cereals in India: Comment," *Am. J. Agr. Econ.* 50:143–145, Feb. 1968.

[18] WITT, LAWRENCE, AND CARL EICHER, *The Effects of United States Agricultural Surplus Disposal Programs on Recipient Countries*, Michigan State Univ. Res. Bull. 2, 1964.

Inter-Fiber Competition and the Future of the United States Cotton Industry

B. Smith and R. Dardis

Markov analysis is employed to investigate the competitive potential of the U. S. cotton fiber industry. Cotton's market share is projected to decline in 17 of the top 20 end uses examined though at a slower rate than in the past. Non-cellulosic, the major competitor, is projected to capture more than 50 percent of the market in 13 end uses. The results indicate the necessity for concerted action by the cotton industry if it is to recapture or even retain its market share. The long time horizons of many end uses provide time for planning and implementing programs designed to improve cotton's competitive position.

COTTON is one of the major agricultural commodities produced in the United States. Since World War II, however, it has faced a decreasing demand for its product that has resulted in a decline in its market share from 75 percent in 1945 to 50 percent in 1967 [4, p. 16; 20, p. 13]. The greatest single reason for the decreased demand has been the introduction of non-cellulosic fibers which have successfully captured a large share of the market formerly held by cotton.

The cotton industry is important economically and politically in the United States as evidenced by the government's commitments to cotton producers, exporters, and users of cotton [23]. Seven million people depend on cotton directly for their incomes including cotton growers, ginners, merchants, warehousemen, cooperatives, manufacturers, and cottonseed crushers. About $14 billion are invested in land and equipment to grow cotton in addition to billions invested in other parts of the industry [8]. Not only is the industry important domestically but also for many years cotton exports were the largest single source of revenue in world trade for this nation [23]. The decline in cotton's competitive position has thus been of increasing concern to both industry and government.

This study employs Markov analysis to investigate inter-fiber competition for major cotton end uses. Projections for future time periods, including equilibrium, are used to evaluate the competitive potential of the United States cotton fiber industry.

B. SMITH *is textile product designer with Personal Products Company, New Jersey.* R. DARDIS *is professor of textiles and consumer economics at the University of Maryland.*

Procedure

Markov process[1]

The classical Markov process is probabilistic in structure. There is a given set of states $(S_1 \cdots S_r)$ and a process which moves successively from one state to another. In a first order Markov process the probability, p_{ij}, that the process will move from S_i to S_j depends only on the state S_i that it occupied prior to the move. Transition probabilities may be represented for every pair of states by a transition probability matrix.

$$(1) \qquad P = \begin{array}{c} \\ S_1 \\ \cdot \\ \cdot \\ S_r \end{array} \begin{array}{c} S_1 \cdots S_r \\ \begin{bmatrix} p_{11} & \cdots & p_{1r} \\ \cdot & \cdots & \cdot \\ \cdot & \cdots & \cdot \\ p_{r1} & \cdots & p_{rr} \end{bmatrix} \end{array}$$

$$p_{ij} \geq 0 \quad \text{and} \quad \sum_j p_{ij} = 1.$$

The matrix P and the initial starting state or vector

$$(2) \qquad s^{(0)} = (s_1^{(0)} \cdots s_r^{(0)})$$

may be used to determine distributions in future time periods. Thus

$$(3) \qquad s^{(0)}P = s^{(1)} \quad \text{and} \quad s^{(n-1)}P = s^{(n)}.$$

Alternatively, $s^{(n)}$ may be obtained from

$$(4) \qquad s^{(0)}P^n = s^{(n)}.$$

[1] For a discussion of the Markov process see Kemeny and Snell [11] and Kemeny *et al.* [12].

Estimation of transition probabilities

The estimation of transition probabilities presents some problems when micro data are unavailable. Market shares must be employed in place of the movements of individual consumers from one fiber to another over time. Telser [17], following the work of Miller [15], suggested a least squares procedure for estimating the transition probabilities in such instances. The basic estimating equation is

$$m_{jt} = \sum_i p_{ij} m_{it-1} + v_{jt} \qquad (i, j = 1 \cdots r; t = 1 \cdots T) \tag{5}$$

where m_{jt} = market share of fiber j at time t and v_{jt} = random variable. While the unrestricted least squares estimates automatically fulfill the condition that $\sum_j p_{ij} = 1$, the non-negativity condition may not be satisfied resulting in inadmissible estimates of the transition probabilities. Telser [17] suggested replacing inadmissible estimates by one or zero and then reestimating the equations until the set of admissible estimates is obtained that minimizes the sum of the squares of error over all relations.

Quadratic programming and minimum absolute deviations have also been employed to estimate the transition probabilities [7, 9, 14, 21]. In the case of minimum absolute deviations non-negative variables are introduced for v_{jt} such that

$$v_{jt} = f_{jt} - g_{jt}. \tag{6}$$

The problem is then,

minimize $\sum_t f_{jt} + \sum_t g_{jt}$ subject to the constraints

$$\sum_i p_{ij} m_{it-1} + f_{jt} - g_{jt} = m_{jt} \tag{7}$$

$$\sum_j p_{ij} = 1 \quad (i, j = 1 \cdots r; t = 1 \cdots T) \tag{8}$$

where f_{jt} and g_{jt} are vertical deviations above and below the fitted line for the set of observations.

Minimum absolute deviations were employed by Charnes *et al.* [5] in a study of executive compensation. Their properties have been discussed by Karst [10], Ashar and Wallace [1], and Lee, Judge, and Zellner [13]. In contrast to Karst's results, the other investigators found that the least squares estimator was more efficient than the minimum absolute deviations (MAD) estimator. However, Lee, Judge, and Zellner [13, pp. 43–44] pointed out that the criterion of performance in "repeated samples" may not be the most meaningful in the social science area since this option is frequently unavailable. They also concluded that the MAD estimator had the property of consistency, took into account the restrictions on the transition probabilities, and appeared to provide a "satisfactory basis for estimating the transition probabilities" [13, p. 137].

Minimum absolute deviations were used in this study to estimate the transition probabilities using data on market shares.[2] The market shares of cotton in major end uses for 1950 to 1967 were obtained from *Cotton Counts Its Customers* [16] and *Textile Organon* [18].[3] Cotton, Rayon/Acetate, Non-Cellulosic, and Wool were the four major fiber categories studied. In some end uses wool consumption was negligible resulting in a three-fiber market.

Results

Current trends in cotton consumption

Absolute cotton consumption in all end uses increased from 4,464.1 million pounds in 1950 to 4,678.0 million pounds in 1967 [4, p. 16; 20, p. 13]. During the same period relative cotton consumption declined from 67.7 percent to 50.0 percent. These trends were paralleled by changes in the top 20 end uses of cotton. Table 1 gives the absolute and relative consumption of cotton in the top 20 end uses in 1950 and 1967.[4] These end uses, which are ranked by

[2] For purposes of comparison the adjusted least squares (ALS) procedure was also employed to estimate the transition probabilities. The similarity between the two methods of estimation is noted in the text.

[3] The time period selected was based on the fact that competition from non-cellulosic first became significant in 1950. Fiber consumption data (and market share data) for each end use were obtained from the following issues of *Textile Organon* [18]: Nov. 1961 (1950–1955), Jan. 1966 (1956–1959), and Jan. 1969 (1960–1967). In the January 1966 issue of *Textile Organon*, the number of end uses reported was reduced by combining two major categories—Girls', Children's, and Infants' Wear Items and Women's, Misses', and Junior Misses' Wear Items—into a new category titled Women's, Misses', Children's, and Infants' Wear. Data for these two categories were combined to ensure continuous coverage of the three end uses affected by this change. Data revisions, including the changing of categories, the difficulty in reporting blends, and the fact that no military end uses are included, are recognized as limitations in the data. However, they are the most comprehensive and reliable source of information at the present time.

[4] Two major end uses—Towels and Toweling and Bags and Bagging, which ranked fourth and seventh, respec-

Table 1. Comparison of absolute and relative cotton consumption in 1950 and 1967 for major cotton end uses

End use	1950* (a)[1]	1950* (b)[2]	1967** (a)	1967** (b)
Sheets and Other Bedding	314.3	100	534.2	93
Men's Utility Clothing	323.4	99	350.8	85
Men's Shirts	275.8	84	305.8	65
Men's Underwear	123.6	98	194.7	88
Drapery, Upholstery and Slipcovers	145.4	72	183.2	38
Apparel Linings	90.5	57	122.8	46
Women's and Children's Dresses	160.1	50	114.0	26
Bedspreads and Quilts	67.6	90	107.4	72
Retail Piece Goods	132.0	61	99.0	54
Rugs and Carpets	92.1	30	88.5	10
Sewing Thread	81.9	98	86.1	82
Narrow Fabrics	61.0	79	80.8	59
Women's and Children's Playwear	79.4	92	80.7	63
Men's Separate Slacks	6.2	9	79.7	33
Shoes and Slippers	60.4	95	69.1	92
Rope, Cordage	57.7	96	66.5	50
Men's Coats and Jackets	30.1	31	64.4	39
Automobile Uses	271.0	47	63.0	12
Women's and Children's Blouses/Shirts	40.2	53	60.0	45
Men's Hosiery	69.5	72	54.2	53

[1] (a) is millions of pounds.
[2] (b) The market share of cotton relative to the other fibers in that end use.
* Data for 1950 taken from [18] *Textile Organon* 32: 177–190, Nov. 1961.
** Data for 1967 taken from [18] *Textile Organon* 40: 6–15, Jan. 1969.

absolute cotton consumption in 1967, accounted for 56–60 percent of total cotton consumption during the period.

There has been an increase in absolute cotton consumption in 15 end uses and a decrease in only five end uses. As a result, overall cotton consumption increased from 2481.7 million pounds in 1950 to 2804.9 million pounds in 1967. For two end uses—Men's Coats and Jackets and Men's Separate Slacks—relative cotton consumption also increased. However, the most frequent trend was an increase in absolute consumption and a decrease in market share which occurred in 13 cases. For the remaining five end uses—Women's and Children's Dresses, Retail Piece Goods, Rugs and Carpets, Automobile Uses, and Men's Hosiery—there was a decrease in both absolute and relative cotton consumption. Four of these five end uses were among the top 10 uses of cotton in 1950.

tively, in 1967—were excluded as the market shares remained stable during the period. They were replaced by Men's Coats and Jackets and Men's Separate Slacks.

Transition probability matrices

The transition probability matrices are given in Tables 2 and 3.[5] The results indicate a high probability of reuse for all fibers and a relatively low degree of fiber switching. The diagonal values in each matrix are all considerably higher than any of the side entries. Nine of the transition probability matrices had absorbing states for non-cellulosic while two had absorbing states for rayon (Table 2). This has serious implications for cotton since it means an eventual decline in its market share to zero.

Table 2. Absorbing matrices

End use	Cotton	Rayon/ Acetate	Non-cellulosic	Wool
Men's utility clothing				
C	.9984	.0003	.0014	—
R	0	1.0000	0	—
N	0	.0208	.9792	—
Men's shirts				
C	.9744	.0146	.0098	.0012
R	.0253	.7942	0	.1805
N	0	0	1.0000	0
W	.7241	0	0	.2459
Men's underwear				
C	.9969	.0007	.0024	—
R	0	1.0000	0	—
N	0	.0169	.9831	—
Bedspreads and quilts				
C	.9873	.0127	0	—
R	.0028	.9847	.0125	—
N	0	0	1.0000	—
Retail piece goods				
C	.9407	.0214	0	.0379
R	.0433	.6947	.0390	.2230
N	0	0	1.0000	0
W	.2346	.7654	0	0
Rugs and carpets				
C	.5157	.0377	0	.4466
R	0	.7247	.1665	.1088
N	0	0	1.0000	0
W	.3500	.1405	0	.5095
Sewing thread				
C	.9909	.0441	0	—
R	.0946	.8695	.0359	—
N	0	0	1.0000	—
Narrow fabrics				
C	.9559	.0441	0	—
R	.0946	.8695	.0359	—
N	0	0	1.0000	—
Women's and children's playwear				
C	.9760	.0201	0	.0039
R	0	.7301	.2699	0
N	0	0	1.0000	0
W	.3491	0	0	.6509
Men's separate slacks				
C	.9002	.0449	.0549	0
R	0	.8253	.0017	.1730
N	0	0	1.0000	0
W	.3050	0	0	.6950
Men's hosiery				
C	.9694	0	.0261	.0045
R	.0634	.8867	0	.0499
N	0	0	1.0000	0
W	.0839	0	0	.9161

[5] Similar results were obtained using the ALS procedure.

Table 3. Non-absorbing matrices

End use	Cotton	Rayon/ Acetate	Non-cellulosic	Wool
Sheets and other bedding				
C	.9971	.0029	0	—
R	.0323	.9494	.0183	—
N	.0800	0	.9200	—
Drapery, upholstery and slipcovers				
C	.9326	.0674	0	—
R	.0264	.9171	.0565	—
N	0	.1111	.8889	—
Apparel linings				
C	.9204	.0529	.0229	.0038
R	.0823	.9177	0	0
N	0	.0060	.9940	0
W	.1464	0	0	.8536
Women's and children's dresses				
C	.9768	0	0	.0232
R	0	.9492	.0372	.0136
N	0	.1251	.8746	.0003
W	0	.1951	.0637	.7412
Shoes and slippers				
C	.9856	.0079	.0064	—
R	.1975	.8025	0	—
N	.2041	.0685	.7274	—
Rope, cordage				
C	.9752	.0091	.0157	—
R	0	.7070	.2930	—
N	0	.0333	.9667	—
Men's coats and jackets				
C	.9383	0	.0617	0
R	0	.8311	0	.1689
N	.0409	0	.9591	0
W	.0561	.0383	0	.9056
Automobile uses				
C	.4458	.5542	0	—
R	.1594	.7801	.0605	—
N	.0023	0	.9977	—
Women's and children's blouses and shirts				
C	.9522	0	.0478	0
R	.1224	.7912	.0563	.0301
N	0	.1690	.8310	0
W	.3410	0	0	.6590

It is also of interest to compare entry and exit rates for the various fibers in the case of non-absorbing matrices (Table 3). In many end uses cotton's exit rate is greater than its entry rate, i.e., consumers are switching from cotton to other fibers at a faster rate than they are switching from other fibers to cotton. This unfavorable balance of trade also means an eventual decline in cotton's market share.

Market share projection

Equilibrium projections were first obtained for the five major end use categories—Men's and Boys' Wear, Women's and Children's Wear, Home Furnishings, Other Consumer Type Products, and Industrial Uses. Non-cellulosic is projected to capture 100 percent of the market in all five categories.[6] While these results are depressing as far as the cotton grower is concerned, they are highly tentative in view of the gross nature of the categories involved. Their most useful function is to provide a framework within which to evaluate changes in the top 20 end uses.

Market share projections for future time periods including equilibrium were obtained for the top 20 end uses of cotton. In this manner it was hoped to determine how rapidly the system was converging to equilibrium. Short-term projections are also less likely to violate the assumptions of the model that the forces underlying the transition probability matrices will remain unchanged. Projections were obtained for 1973, 1978, and 1999. Table 4 shows changes in cotton's market share over a 48-year period using actual and projected values. Tables 5 and 6 give the same data for rayon/acetate and non-cellulosic, respectively.[7]

Cotton's equilibrium market share is zero for 13 of the 20 end uses and is less than 50 percent in four other end uses.[8] In contrast, rayon/acetate and non-cellulosic are projected to dominate the market in four and thirteen end uses, respectively. For two end uses—Sheets and Other Bedding and Shoes and Slippers—1967 cotton values are very close to convergence. However, as was pointed out, the results of Sheets and Other Bedding must be discounted. Five end uses will have converged or become close to converging by 1983. These end uses are Drapery, Upholstery, and Slipcovers; Rugs and Carpets; Men's Coats and Jackets; Automobile Uses; and Women's and Children's Blouses and Shirts. Two end uses—Women's and Children's Dresses and Men's Separate Slacks—will have a relatively small market share (12 percent) by 1999 which converges to zero in equilibrium. For the remaining 11 end uses there seems to be a much longer time horizon, as 1999 values still differ to a considerable extent from equilibrium values. Concentration on these particular end uses which accounted for a high proportion of cotton consumption in 1967 would assist in

[6] ALS estimates were similar with the exception that the market share of non-cellulosic declined to 90 percent and 48 percent in Women's and Children's Wear and Industrial Uses, respectively, while cotton's market share increased to 5 percent in one end use—Women's and Children's Wear.

[7] In a comparison of ALS and MAD equilibrium values it was found that 13 of the 20 projection sets were in close agreement. Most of the discrepancies arose from variations in absorbing states for rayon/acetate and non-cellulosic.

[8] Cotton's market share in Sheets and Other Bedding is undoubtedly overstated due to the increased use of polyester/cotton blends in bedsheeting in recent years [4, p. 18].

Table 4. The market share of cotton from 1951 to 1999 and at equilibrium

End use	1951[a]	1959[b]	1967[c]	1975	1983	1999	Equilibrium
	Percent						
Sheets and Other Bedding	99.8	96.6	93.5	93.7	93.7	93.6	93.4
Men's Utility Clothing	99.1	98.7	85.1	84.0	82.9	80.7	0
Men's Shirts	82.2	87.8	65.8	62.1	58.0	50.2	0
Men's Underwear	96.4	97.3	88.7	86.5	84.4	80.2	0
Drapery, Upholstery, and Slipcovers	66.9	55.3	38.0	29.6	25.3	21.9	20.6
Apparel Linings	55.0	46.2	45.9	41.9	38.3	32.7	17.3
Women's and Children's Dresses	50.7	60.7	26.2	21.7	18.0	12.4	0
Bedspreads and Quilts	90.5	82.9	72.1	65.6	59.9	50.1	0
Retail Piece Goods	62.1	64.8	54.0	50.5	46.7	39.5	0
Rugs and Carpets	40.1	27.9	9.8	6.2	4.2	1.9	0
Sewing Thread	96.1	91.0	81.8	79.1	76.3	70.8	0
Narrow Fabrics	79.3	67.9	59.1	53.0	48.7	41.6	0
Women's and Children's Playwear	93.5	92.5	62.6	54.2	46.1	33.3	0
Men's Separate Slacks	10.1	56.8	33.2	28.2	21.6	12.0	0
Shoes and Slippers	94.9	93.9	92.4	93.1	93.2	93.3	93.3
Rope, Cordage	93.8	83.0	50.0	40.9	33.4	22.3	0
Men's Coats and Jackets	30.1	37.9	39.0	39.7	40.0	40.1	39.9
Automobile Uses	48.5	15.1	12.0	6.5	4.9	3.0	1.4
Women's and Children's Blouses and Shirts	57.1	74.0	45.3	53.2	56.7	57.8	57.9
Men's Hosiery	70.2	68.0	53.1	43.6	35.9	24.3	0

[a] Data for 1951 taken from [18] *Textile Organon* 32:177–190, Nov. 1961.
[b] Data for 1959 taken from [18] *Textile Organon* 37:8–20, Jan. 1966.
[c] Data for 1967 taken from [18] *Textile Organon* 40:6–15, Jan. 1969.

Table 5. The market share of rayon/acetate from 1951 to 1999 and at equilibrium

End use	1951[a]	1959[b]	1967[c]	1975	1983	1999	Equilibrium
	percent						
Sheets and Other Bedding	0.2	3.1	4.3	4.7	4.9	5.2	5.4
Men's Utility Clothing	0.7	0.5	1.7	4.0	6.1	9.8	100
Men's Shirts	13.1	6.8	6.3	4.8	4.3	3.7	0
Men's Underwear	3.0	1.4	4.2	5.7	7.3	10.6	100
Drapery, Upholstery, and Slipcovers	32.3	33.6	44.2	48.9	50.8	52.1	52.6
Apparel Linings	41.0	39.2	35.9	32.8	30.3	26.4	15.9
Women's and Children's Dresses	43.8	26.6	48.9	54.9	58.2	62.8	72.7
Bedspreads and Quilts	9.4	16.7	23.9	27.8	30.6	33.9	0
Retail Piece Goods	29.6	23.8	24.0	21.4	19.4	16.4	0
Rugs and Carpets	14.3	21.3	12.6	6.1	3.9	1.7	0
Sewing Thread	0.3	2.9	3.2	2.6	2.4	2.3	0
Narrow Fabrics	19.0	25.3	17.6	18.4	17.6	15.2	0
Women's and Children's Playwear	3.4	4.3	11.2	4.9	3.7	2.6	0
Men's Separate Slacks	63.7	12.4	16.4	9.7	7.0	3.9	0
Shoes and Slippers	4.9	4.1	4.9	4.6	4.5	4.5	4.5
Rope, Cordage	1.8	4.2	7.1	7.0	7.5	8.4	10.2
Men's Coats and Jackets	15.5	9.0	8.2	5.3	3.6	1.8	0
Automobile Uses	47.2	59.1	25.1	20.2	14.7	8.6	3.6
Women's and Children's Blouses and Shirts	36.0	9.3	23.1	21.1	18.9	18.2	18.1
Men's Hosiery	13.1	3.9	1.3	0.5	0.2	0	0

[a] Data for 1951 taken from [18] *Textile Organon* 32:177–190, Nov. 1961.
[b] Data for 1959 taken from [18] *Textile Organon* 37:8–20, Jan. 1966.
[c] Data for 1967 taken from [18] *Textile Organon* 40:6–15, Jan. 1969.

Table 6. The market share of non-cellulosic from 1951 to 1999 and at equilibrium

End use	1951[a]	1959[b]	1967[c]	1975	1983	1999	Equilibrium
				percent			
Sheets and Other Bedding	0	0.3	2.1	1.6	1.4	1.2	1.2
Men's Utility Clothing	0.2	0.8	13.2	12.0	11.0	9.4	0
Men's Shirts	0.7	3.5	26.7	31.7	36.5	45.0	100
Men's Underwear	0.6	1.2	7.1	7.8	8.3	9.2	0
Drapery, Upholstery, and Slipcovers	0.7	11.1	17.7	21.5	23.9	25.9	26.7
Apparel Linings	0	12.6	17.1	24.2	30.3	40.0	66.3
Women's and Children's Dresses	1.7	7.0	18.0	18.3	19.0	20.3	23.5
Bedspreads and Quilts	0.1	0.4	4.0	6.6	9.5	16.0	100
Retail Piece Goods	0.1	2.9	14.2	21.3	27.7	38.9	100
Rugs and Carpets	0	9.7	68.3	79.9	86.7	94.0	100
Sewing Thread	3.6	6.1	14.9	18.2	21.2	26.8	100
Narrow Fabrics	1.5	6.8	23.3	28.5	33.7	43.2	100
Women's and Children's Playwear	0.1	2.7	24.3	40.3	49.7	63.6	100
Men's Separate Slacks	2.9	16.1	41.6	55.5	66.7	81.5	100
Shoes and Slippers	0.1	2.0	2.7	2.2	2.2	2.2	2.2
Rope, Cordage	4.4	12.7	42.9	52.1	59.0	69.2	89.8
Men's Coats and Jackets	4.0	8.6	30.1	38.3	44.5	52.2	60.1
Automobile Uses	4.3	25.8	62.9	73.3	80.4	88.4	94.9
Women's and Children's Blouses and Shirts	3.3	14.1	30.9	23.7	22.6	22.4	22.4
Men's Hosiery	6.6	17.3	42.7	52.9	61.3	73.8	100

[a] Data for 1951 taken from [18] *Textile Organon* 32:177–190, Nov. 1961.
[b] Data for 1959 taken from [18] *Textile Organon* 37:8–20 Jan. 1966.
[c] Data for 1967 taken from [18] *Textile Organon* 40:6–15 Jan. 1969.

stabilizing, if not recouping, part of its losses in the future.[9]

Conclusions

This study employed Markov analysis to investigate inter-fiber competition and to evaluate the competitive potential of the United States cotton fiber industry.

A comparison of equilibrium values indicated that cotton's market share would decrease to 0 for 13 end uses including 7 of the top 10 end uses. In contrast an increase was projected for only three end uses, two of which were in the lowest quartile. Non-cellulosic was the major competitor since it was projected to capture more than 50 percent of the market in 13 end uses as opposed to 4 for rayon/acetate. Cotton's major losses were projected to occur in Men's Wear and Home Furnishings—the two major categories of cotton consumption in 1967.

Projected market shares for 8, 16, and 32 years using MAD estimates were also used to determine the rapidity of convergence to equilibrium. In general, the decline in cotton's market share in the 16-year period prior to 1967 was greater than that projected to occur after 1967. By 1983 only seven end uses will have approached convergence. Eleven end uses have 1999 values which differ considerably from equilibrium values, indicating that the time horizon is more distant than 32 years. This information gives an indication of the amount of time available for planning and implementing cotton programs designed to improve its competitive position.

One limitation of Markov analysis for studying inter-fiber competition must be mentioned. This is the occurrence of absorbing matrices. In this study most of the absorbing states pertained to non-cellulosic which implies the eventual disappearance of blends. However, blending has been the major strategy whereby polyesters entered markets unsuitable for 100 percent polyester. In addition the most successful durable press method depends on cellulosic cross-linking, which means either cotton or rayon must be present to obtain these results. The equilibrium market shares of non-cellulosic have been overestimated, therefore, in end uses where blends are important. This qualification does not invalidate market share projections.

[9] In view of rapid technological change in the fiber industry, projections were also based on a 10-year period (1957–1967). While cotton's market share tended to be lower in most instances, it was fairly close to previous results. The greatest market share reduction occurred for Women's and Children's Wear, reflecting the more rapid deterioration of cotton's competitive position in this category in recent years.

for future time periods since the time horizon for most of these end uses is considerably longer than 32 years.

A further qualification concerns the dynamic nature of the fiber industry and the fact that changes since 1967 may influence the transition probabilities and, hence, market share projections. For example, the shift from woven to knit good production may have a significant impact on cotton's competitive position as may the development of 100 percent permanent press cotton.

While the results must be interpreted with caution, they are of value in predicting what would have occurred if the forces in the system had remained unchanged. As Collins and Preston [6, p. 306] pointed out, "The equilibrium distribution is of interest not as a forecast of what the future state of the industry will be but as a projection of what it would be if the observed pattern of movement continued. It is thus an indication of tendencies at work within the distribution." A comparison of actual and projected market shares would thus serve to indicate the impact of technological and marketing factors on the competitive position of cotton and other fibers. A more extensive investigation might include a comparison of transition probabilities and market share projections based on two different time periods such as 1957–67 and 1968–78.[10] While such comparisons are not feasible at the present time and are hence beyond the scope of this paper, they would provide useful information concerning the changing nature of inter-fiber competition in the U. S.

If cotton is to recapture or retain its present market share, various competitive strategies will have to be employed. According to recent studies [2, 3, 22], price, quality, and promotion are major variables influencing demand. The competitive weapons against rayon appear to be both price and quality with price becoming of major importance in connection with the high wet modulus rayon. The primary strategy for cotton against non-cellulosic appears to be quality, which indicates that cotton must increase its research programs in this area. In both instances the effects of increased promotion would seem to offer little positive return unless cotton is competitive in the areas of price and quality.

In discussing inter-fiber competition it is important to examine the particular market structure in which the various fibers are grown or developed. The synthetic fiber producers are few in number, operate in a highly technical research oriented environment, and have the ability to combine all three variables—price, quality, and promotion—in an optimum manner. In contrast the cotton fiber industry consists of many small units with a consequent lack of control over product quality and price. Under such circumstances promotion may be expected to play a relatively minor role. Decisions concerning price and quality of cotton have also reflected the influence of government rather than the marketplace itself with a consequent loss of potential markets for cotton in the long run. The situation has been aggravated by the inability of natural fiber producers to control supply and price to the same degree as the man-made fiber producers. Thus, increased promotion of cotton in recent years was negated by rising cotton prices due to unpredictable supply situations.

The 1966 Cotton Research and Promotion Act [19] is an indication of awareness on the part of the cotton industry of the necessity for concerted action. Only by such actions may the atomistic cotton fiber industry hope to compete with the oligopolistic man-made fiber industry. The basic question is whether voluntary co-operation among different interest groups will be capable of developing the appropriate competitive strategies. It is possible that a restructuring of the cotton fiber industry may be necessary if it is to regain or even retain its share of the market.

[10] Reasons for selecting these particular time periods include the passage of the Cotton Research and Promotion Act in 1966, increased promotion of blends as opposed to 100 percent cotton by the cotton fiber producers, and the expansion of knit goods since 1967.

References

[1] ASHAR, V. G., AND T. D. WALLACE, "A Sampling Study of Minimum Absolute Deviations Estimators," *Oper. Res.* 11:747–758, Sept.–Oct. 1963.

[2] BARLOWE, R. C., "Analysis of Cotton and Man-Made Fiber Substitution in End Use Item Consumption in the United States," unpublished M.S. thesis, University of Maryland, 1967.

[3] ———, AND J. R. DONALD, "Recent Changes in Selected Cotton End Uses," *Cotton Situation*, USDA, ERS, CS-243, Oct. 1969.

[4] ———, "U. S. Demand for Cotton: Trends and Prospects," *Cotton Situation* USDA, ERS, CS-250, March 1971.

[5] CHARNES, A., W. W. COOPER, AND R. O. FERGUSON,

"Optimal Estimation of Executive Compensation by Linear Programming," *Mgt. Sci.* 1:138–151, Jan. 1955.

[6] COLLINS, N. R., AND L. PRESTON, "Growth and Turnover of Food Processing Firms," Proceedings of the Annual Meeting of the Western Farm Economic Assoc., Stanford University, Aug. 23–26, 1960.

[7] FISHER, W. D., "A Note on Curve Fitting with Minimum Deviations by Linear Programming," *J. Am. Stat. Assoc.* 56:359–362, June 1961.

[8] HORNE, M. K., AND D. S. WELLFORD, "The Economic Outlook for Cotton," A Report before the National Cotton Council's 31st Annual Meeting in Hot Springs, Jan. 27, 1969.

[9] JARRETT, F. G., AND W. DENT, "Fiber Substitution: A Markov Process Analysis," *Australian Econ. Papers* 5:107–130, June 1966.

[10] KARST, O. J., "Linear Curve Fitting Using Least Deviations," *J. Am. Stat. Assoc.* 53:118–132, March 1958.

[11] KEMENY, J. G., AND J. L. SNELL, *Finite Markov Chains*, Princeton, De Van Nostrand Company, Inc., 1960.

[12] KEMENY, JOHN G., HAZELTON MIRKIL, J. LAURIE SNELL, AND GERALD L. THOMPSON, *Finite Mathematical Structures*, Englewood Cliffs, Prentice-Hall, 1959.

[13] LEE, T. C., G. G. JUDGE, AND A. ZELLNER, *Estimating the Parameters of the Markov Probability Model from Aggregate Time Series Data*, Amsterdam, North-Holland Publishing Co., 1970.

[14] LEE, T. C., G. G. JUDGE, AND T. TAKAYAMA, "On Estimating the Transition Probabilities of a Markov Process," *J. Farm Econ.* 47:742–762, Aug. 1965.

[15] MILLER, G. A., "Finite Markov Processes in Psychology," *Psychometrika* 17:149–167, 1952.

[16] National Cotton Council of America, *Cotton Counts Its Customers*, Memphis, National Cotton Council, selected issues.

[17] TELSER, L. G., "Least-Squares Estimates of Transition Probabilities," in *Measurement in Economics; Studies in Mathematical Economics and Econometrics in Memory of Yehuda Grunfeld*, eds., Carl F. Christ *et al.*, Stanford, Stanford University Press, 1963, pp. 270–292.

[18] Textile Economics Bureau, Inc., *Textile Organon*, New York, Textile Economics Bureau, selected issues.

[19] U. S. Congress, Senate, *Cotton Research and Promotion Act*, Washington, D. C., U. S. Government Printing Office, 1966.

[20] U. S. Department of Agriculture, *Statistics on Cotton and Related Data, 1930–1967*, ERS Stat. Bull. 417, March 1968.

[21] WAGNER, H. M., "Linear Programming Techniques for Regression Analysis," *J. Am. Stat. Assoc.* 54:206–212, March 1959.

[22] WARD, LIONEL E., "Interfiber Competition with Emphasis on Cotton," unpublished Ph.D. thesis, University of California, Davis, 1968.

[23] WHITAKER, R., "The Cotton Surplus Problem 1930–1966," in *Cotton and Other Fiber Problems and Policies in the United States*, National Advisory Commission on Food and Fiber, July 1967, pp. 87–166.

Socioeconomic Behavior of Cattle Ranchers, with Implications for Rural Community Development in the West*

Arthur H. Smith and William E. Martin

This paper extends the argument that cattle ranching and ranchers can be better understood by viewing the ranch resource as generating both production and consumption outputs. It was found that nonmonetary outputs of ranch ownership are the most significant factors in explaining high sale prices of Arizona ranches. Land fundamentalism, rural fundamentalism, and conspicuous consumption/speculative attitudes are the most important of these consumption outputs. The analysis suggests that small town viability and growth in the arid Southwest, and possibly in the West as a whole, may be more likely to occur if rural development policies are not predicated on the economic impact of surrounding ranches.

The crux of this argument is that cattle ranching in Arizona, and possibly by extension in the whole arid Southwest, is no longer a subject for discussion under the category of "commercial agriculture," but has, in fact, become a legitimate field of inquiry in "community development and human resources."

This argument will be developed in the following way. First, a brief summary of the results of previous research which show the problems of viewing ranching in the traditional production-economics–commercial-agricultural framework will be given. Second, some results of the authors' recent socioeconomic analysis of the goals and attitudes of Arizona ranch owners which suggest an alternative framework for viewing operations of the range cattle economy will be reported. This framework views cattle ranching as a consumer item comprised of many components, including the utility obtained from consumption of such intangibles as "love of land" and "love of rural values." Finally, implications of such goals and attitudes on the development of rural ranching communities are discussed.

Ranching as Commercial Agriculture

Based on the market prices of bona fide commercial ranches in Arizona, computed net returns to capital and management range from negative to 1 or 2 percent [3]. (Similar results have been obtained in the other western states [11].) Market prices are related to the relative mix of public and private lands of which a given ranch is composed, but no matter what the mix or whether the ranch contains any private deeded land, the market price is well above a rational value based on the capitalized value of the ranch's earning potential [7]. Bostwick [2] has suggested that such results could be explained by including in the computation of net returns the values of land appreciation, income tax savings, and opportunities for using financial leverage. The authors agree that part of the difference between market prices based on the value in beef production and land appreciation versus actual market prices can be explained in the manner that Bostwick suggests, but large differences still remain. Rental rates for private rangeland of approximately $650 per animal unit are obtained when converted to present-value sale prices (nearly three times the estimated reasonable "economic" price per animal unit), where possibilities of land value appreciation accruing to the rancher do not exist [7]. It is also noted that cattle ranch prices in Arizona have remained relatively constant over the past decade, thus maintaining an almost constant unexplained opportunity cost above the ranches' value in use. Tax savings without special conditions or significant land appreciation do not occur [6].

Thus, looking at the demand side of the market price equation, purchases of Arizona ranches apparently are not made for the purpose of maximizing returns on investment (a combination of current income and land appreciation). On the supply side of the equation, ranches are selling at such high prices that an extremely low return on the opportunity cost of investment is implied on all retained ranches.

It is hypothesized that the unexplained difference between computed rational market

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Arthur H. Smith *and* William E. Martin *are assistant agricultural economist and professor of agricultural economics, respectively, at the University of Arizona.*

prices based on beef production and land appreciation versus actual market prices is related to the ranchers' or investors' desires for consumption goods.[1] The implications of this hypothesis, if true, affect efforts in economic research, government policy, and community and human resources development.[2] If ranchers are primarily purchasing (or maintaining control of) a consumption good for their own satisfaction, production theory may not apply to the operations of a ranch at all. If commercial agriculture is that sector of agriculture which responds to factor and product market stimuli, the Arizona range livestock industry is not a part of commercial agriculture [8] and cannot be analyzed within the traditional framework of production theory.

In discarding the pure theory of the firm approach to explain the economic behavior of Arizona cattle ranchers, the "satisficing" concept is found to be a highly useful analytical tool in explaining their socioeconomic behavior. As firm owners try to maximize a utility function that includes other components besides profits, it is likely that the entrepreneur may not care about maximizing profits, but would rather earn a return he regards as satisfactory [5, 9, 13, 14]. However, the relationship between less than profit-maximizing behavior and survival becomes ambiguous. While it may be possible for a firm to survive if the level of profit is positive, it cannot continually survive if it is producing outputs yielding negative profits. Eventually, all its resources would be used up. If a firm had outside sources of income, it could survive if the sum of profits and net income from other sources is greater than zero [1].

Goals and Attitudes of Arizona Ranch Owners

The socioeconomic research reported here focuses on the supply side of the market for ranches. A ranch owner is directly or implicitly equating the value of money foregone to him in not selling the ranch to the amount of satisfaction that he obtains through ranch ownership. If the marginal valuation for the ranch in production and consumption is greater than the market price for ranches, the ranch owner would indicate that his ranch is presently not for sale; if the contrary is true, then the present ranch owner would indicate that his ranch is for sale at current market prices. Certainly some ranchers do tend to act as "economic men" in the traditional production economics sense. The question is, what percentage? If all were "economic men," ranch sale prices would never have become as high as they are.

In conformity with the hypothesis of this paper, consumption aspects of ranching are additional outputs received from ranching and ranch ownership which can help explain the high sale prices of ranches. Ranchers would be reluctant to part with their ranches if they could not expect to receive the social and psychological benefits of ranch ownership in similar form and to a similar degree elsewhere. The major goal of Arizona cattle ranchers appears to be to maintain the ranch as a business, home, and way of life. The effect of this evaluation is to cause them to place a higher value on the ranch resource and to ask for a higher price in the market. Ranchers can obtain these high prices because persons outside the present ranching economy are willing to purchase ranches at these prices since they believe they can obtain greater satisfaction from the use of their wealth in ranch ownership than elsewhere.

Eighty-nine usable personal interview schedules containing questions on both economic and attitudinal variables were obtained from a random sample of Arizona ranch owners. Factor analysis was used on the responses to 33 questions from this questionnaire. Factor analysis is appropriate where one wishes to reduce the phenomena in a domain into a relatively small number of dimensions or factors. It allows the researcher to discover interrelationships among variables without making in advance any assumptions as to how they relate to each other. This analysis extracted 11 orthogonal factors from these 33 variables (see Appendix) based upon the criterion that only those factors with eigenvalues greater than unity be considered significant [4]. For 11 factors, 69.2 percent of the variance of the original variables is explained; more than 11 factors contribute little additional explanation of variance.

The 11 factors generated by this analysis are viewed as indicating the significant goals and attitudes surrounding ranch ownership commonly held by Arizona ranchers. These goals and attitudes are (1) land fundamentalism, (2) family fundamentalism, (3) rural fundamentalism, (4) resource protection goal,

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[1] Bostwick, along with Rodewald [12], now apparently agrees with our general hypothesis.

[2] See [7] for implication of the consumption aspects of ranch ownership upon grazing fee policy.

(5) conspicuous consumption/speculative attitudes, (6) income satisficing, (7) wealth satisficing, (8) agricultural orientation, (9) immobility, (10) local orientation, and (11) local social satisficing.

These attitudes and goals are defined and discussed in detail in [15] where the factor loadings (relative importance) of individual variables on each factor are listed. Factor loadings can show both positive and negative correlations with a factor. Contrasting concepts (i.e., variables) can load on the same factor, for in reality they are measuring opposite ends of the same underlying dimension. Loadings were considered significant if the absolute value was .263 or above at $\alpha = .05$ with 54 degrees of freedom [10, p. 138]. However, interpretation of the factor analysis as discussed in [15] has been somewhat modified. Further study has resulted in giving greater weight to the satisficing concept and its implications for small town survival and community development in the West.[3]

For purposes of discussion the 11 factors may be placed into one of four basic groups—ranch fundamentalism, conspicuous consumption/speculative attitudes, economic satisficing, and ties to the local area and community. The four categories are not mutually exclusive for any given rancher; for example, a rancher who is an absentee owner and evidences characteristics of conspicuous consumption/speculative behavior may also be found to hold ranch fundamentalistic attitudes.

Ranch fundamentalism

Ranch fundamentalism is defined as the attitude that being a cattle rancher leads to a higher state of total well-being than an alternative mode of making a living and way of life could provide. It is comprised of family, land, and rural fundamentalism attitudes, plus a resource protection goal. These subsets of the concept ranch fundamentalism, especially land fundamentalism, are attitudes held not only by old-time ranchers but also by recent purchasers of ranch property. They are separate but interrelated attitudes about the family, rural values, and land itself. The resource protection concept relates to the group of ranchers who have large ranches, do not live on the ranch, and are members of one or more cattle associations. The cattle association serves as a protective institution in attempting to maintain rangeland holdings for its members' exclusive use. This role is evidenced in such activities as fighting the reclassification of rangeland into wilderness areas or supporting antisportman legislation in an effort to keep other people off "their" range.

Conspicuous consumption/speculative attitudes

Conspicuous consumption/speculative attitudes are defined as the desire to obtain the social and psychological benefits of ranch ownership in a period of time in which the ranch owner is actively interested in the possibility of ranchland appreciation. Presumably, these ranch owners would be likely to sell their ranches if buyers could be found who would pay a higher price for the resources of the ranch than the present owners had paid at an earlier point in time. However, this does not mean that appreciation has actually occurred or that an investor has been actively trading ranches, but only that a conspicuous consumption/speculative attitude is discernible on the part of some ranch owners. Conspicuous consumption is mostly associated with ranch owners who recently purchased ranches and have absentee permanent residences in the larger urban areas of the state or out of state. Thus, one possible explanatory hypothesis of why variables relating to both land speculation and the social aspects of owning a ranch are correlated is that the ranch owner is eager to "capture" the social benefits of ranch ownership in the period of time he is "waiting" for land values to increase. It is also possible the original motive for investing in a ranch at relatively high prices was social and psychological and the rationalization of this desire was economic.

Economic satisficing

The economic satisficing attitudes of ranchers are comprised of an income and a wealth satisficing component. Income satisficing is the term used to describe the monetary attitude of ranchers who are satisfied with the low or negative return on investment, do not have all their income coming from ranching, and yet expect their children to enter ranching and forego monetary opportunities elsewhere. This suggests that the income received directly from ranching may be considered "good enough."

[3] The number of factors with their component variables are not changed from [15]. Factors 4, 5, and 7 above are renamed from factors 2, 7, and 6, respectively, in [15]. The selection of an appropriate "name" for a cluster of variables composing a factor has no special formula and can be considered an intuitive art.

However, this attitude may be dependent upon the rancher's belief that he would be able to get an outside job in the local area if the economic need occurred. With 20 percent of the ranchers in this sample presently holding outside jobs in the local area in a nonprofessional or nonmanagerial capacity, one cannot escape the conclusion that maintaining the ranch as a home and way of life is the rancher's most important goal —provided he can find a way to survive financially in the local area.

The wealth satisficing attitude relates to those ranchers who feel that holding land for appreciation purposes is worthwhile, who intend to increase the size of their ranch (presumably for purposes of beef production), and yet find the low percent return on investment in ranching satisfactory. These ranchers are not "actively" speculating in ranchland and likely will not be able to increase the size of their ranches to obtain economies of size because neighboring land already has incremental values over its value in beef production. Thus, there seems to be a wealth satisficing attitude surrounding ranching just as there is an income satisficing attitude, since the value of ranchers' assets would generally produce a greater monetary return elsewhere.

Ties to local area and community

The ties to the local area and community held by many ranchers are a reflection of the strength of conviction of their ranch fundamentalistic and economic satisficing attitudes. Most ranchers feel satisfied to remain in the local area and would be reluctant to relocate elsewhere. These ties suggest that it may take a higher price to induce them to part with their ranches than would be necessary if local ties did not exist. Their agricultural and local orientations give rise to immobility almost regardless of the market price of ranches. Arizona ranch owners act no differently in this regard than coal miners in Appalachia, and policy proposals regarding rural land use alternatives will need to take into account this attitude toward the local community.

A Test of the Factors as Explanatory Variables

In order to test which of these goals and attitudes or combination thereof explains why ranch owners are willing to remain in ranching in the face of the low or negative return on investment, the technique of discriminant analysis was used to determine if a significant difference in goals and attitudes exists between those ranchers who are presently willing to sell their ranches and those who are not. It is hypothesized that the goal in owning a ranch is some desired proportion between production and consumption outputs accruing to the ranch owner. It is difficult to predict *a priori* what ranchers will do with their ranches once nonmonetary outputs are allowed into the analysis; therefore, a positivistic rather than a normative approach must be taken.

The purpose of discriminant analysis is to classify an individual as belonging to one of two or more groups of individuals based on various attributes of the sample or population from which the individual came. Discriminant analysis is also useful with research problems involving a comparison of two or more groups in which it is necessary to establish whether significant differences actually exist between groups. These differences, once established, can be utilized in classifying the group membership of an individual not included in the original sample at some level of probability of success.

The procedure for discriminating between which goals and attitudes held by ranchers place them in one group or the other is to find a critical value for which a linear combination of the goals and attitudes used as variables will minimize the overlap between the two groups.

The basic linear equation used to define group membership (when only two groups are involved) for each individual is

$$d_j = \sum_{i=1}^{m} a_i x_{ij}$$

$$i = 1, \cdots, m \quad \text{for } m \text{ variables}$$

$$j = 1, \cdots, n \quad \text{for } n \text{ individuals.}$$

In this equation, d_j is the value of the discriminant function for the jth individual, the a's are estimated coefficients of the discriminant function, and the x's are the variables used in the analysis. When the above equation is evaluated for an individual, his computed score is then compared to a critical value, c, which is used to separate groups:

$$d_j \gtrless c.$$

Following this procedure with each individual in the sample, a final classification matrix is produced which shows the effectiveness of separating the sample into two groups.

In estimating the discriminant function from the sample an F-level of 2.75, corresponding to

the 90 percent confidence level, was chosen as the lower cutoff level of acceptability for inclusion of a variable. Tables 1 and 2 summarize the results of the discriminant analysis of the ranchers' intent to sell or keep the ranch. Table 1 lists the significant explanatory variables, the values of the estimated coefficients and their associated F values, and the estimated critical value. Values more negative than −.37222 indicate that the rancher would keep the ranch; values more positive than −.37222 indicate that he would sell the ranch. Table 2 shows the effectiveness of the separation into the two groups of ranchers.

Only three of the eleven goals and attitudes generated by the factor analysis and used as independent variables in the discriminant analysis have significant F-values for distinguishing differences between the two groups of ranch owners. The three variables in rank order of significance are (1) land fundamentalism, (2) conspicuous consumption/speculative attitudes, and (3) rural fundamentalism. All other goals and attitudes used as variables are not found to be significant in explaining differences between the two groups and therefore are not included in the discriminant function finally used. These mostly nonmonetary factors provide the basis for documenting that ranching and ranch ownership provide consumption outputs which ultimately carry exchange value in the market. The purely economic variables do not differentiate between groups; this suggests that the rancher's decision-making process is dependent upon attitudinal aspects at the margin. With knowledge of these three basically consumption factors alone, it is possible to predict with approximately 80 percent accuracy which ranchers would consider selling their ranches and which ranchers would not consider selling at current market prices.

The final classification matrix for the two groups indicates that the discriminant analysis correctly classifies 20 of the 25 ranch owners

Table 1. Estimated coefficients of the discriminant analysis

Variable	Value of the estimated coefficient	F value
Land fundamentalism	−.52522	18.0143
Conspicuous consumption/speculative attitude	.42858	11.6037
Rural fundamentalism	.22795	4.4930
Critical value	−.37222	

Table 2. Final classification matrix of discriminant analysis

Classification from sample	Classification from discriminant analysis	
	Sell	Keep
Sell	20	5
Keep	13	51

who said they would consider selling their ranch. Of the 64 ranchers who indicated that their ranches are not for sale at any price near current market value, the discriminant analysis correctly classifies 51. Thus, the discriminant analysis correctly classifies 71 of the 89 ranchers, or 79.8 percent, with an approximately equal percentage of misclassification (20 percent) occurring within each group. Seventy-three percent of all ranchers can be correctly classified on the basis of their factor scores for land fundamentalism alone. The additional two factors of conspicuous consumption/speculative attitudes and rural fundamentalism are statistically significant, but add only 3.4 percentage points each as they are included in a step-wise discriminant analysis.

The discriminant analysis shows that if a rancher has strong land fundamentalistic attitudes he will be placed into the "keep" group. This is as one would expect; a ranch owner who feels strongly about land and land ownership would be less likely to sell his ranch, all other things being equal, than a rancher who does not share this attitude. Land fundamentalism, simply defined, is the attitude that a greater amount of satisfaction can be received from associating directly with the physical environment rather than with the "man-made." Variables clustering with the land fundamentalism factor, their abbreviated definitions, their factor loading,[4] and interpretation when the attitude is strongly held are listed below.

Land Fundamentalism

Variable	Variable Abbreviation	Factor Loading
14	Land ownership: closer to earth	.805
15	Land ownership: fundamental values	.777
12	Ranching: fundamental values	.705
8	Ranching: land for its own sake	.416
10	Ranching: good for children	.360
11	Ranching: away from cities	.337

[4] Signs on factor loadings relate only to the coding of the original data and are not necessarily correlated with the sign of the final factor score. For example, the signs for all variables loading on the rural fundamentalism factor are negative, yet the factor score, *when the attitudes described by the factor are strongly held*, is positive.

If a rancher has strong land fundamental attitudes, his factor score is positive and he would feel that:

1. land ownership permits him to feel closer to the earth.
2. land ownership causes him to hold more fundamental personal values.
3. ranch ownership allows him the opportunity of getting back to fundamental personal values.
4. ranch ownership provides him the opportunity of owning land for its own sake.
5. ranch ownership provides him a good place to raise children.
6. ranch ownership allows him to live away from cities at a place of his own.

The land fundamentalism factor was the most significant attitude in determining why ranchers stay on their ranches at the current high market prices. It is possible that other variables would measure the strength of this attitude more completely. However, the authors definitely feel that the strength of ranchers' attitudes toward land itself is the key to understanding why ranchers do not act as "economic men."

Conspicuous consumption/speculative attitudes and rural fundamentalism are the two other significant factors in explaining ranchers' decision processes. Both factors, when the attitudes comprising the factors are strongly held, place ranchers into the "sell" group. These results may be better understood by examining the interrelationship of variables to their factors before proceeding with further discussion.

Conspicuous Consumption/Speculative Attitudes

Variable	Variable Abbreviation	Factor Loading
7	Ranching: land speculation	.828
32	Active speculation in land	.793
5	Social organization member	.392
31	General belief: speculation worthwhile	.383
26	All income from ranching	−.357
8	Ranching: land for its own sake	.353
11	Ranching: away from cities	.286

If a rancher has strong conspicuous consumption/speculative attitudes, his factor score is positive and:

1. he would feel that ranch ownership provides him the opportunity to speculate on ranchland.
2. he is actively speculating on the value of his ranchland.
3. he is a member of one or more exclusive social organizations.
4. he believes that holding ranchland for land appreciation purposes is worthwhile.
5. he does *not* receive all of his income from ranching.
6. he would feel that ranch ownership provides him the opportunity to own land for its own sake.
7. he would feel that ranch ownership allows him to live away from cities at a place of his own.

Ranch owners with conspicuous consumption/speculative attitudes are found to be members of exclusive urban social organizations (private clubs not including fraternal organizations) and tend to use the ranch as a social "retreat." However, variables relating to land speculation are associated with conspicuous consumption, giving this factor a monetary as well as a social and psychological dimension. If conspicuous consumption/speculative attitudes measured only the social and psychological benefits of ranch ownership, then it would be likely that conspicuous consumption attitudes would place an owner, all other things being equal, into the "keep" group. However, in this case, the technique of discriminant analysis would appear to have placed correctly the owner into the "sell" group because of the strength of the speculative attitude component. A person who has recently purchased a ranch at a relatively high price and who is actively speculating on its value would sell that ranch if a price higher than his original purchase price could be obtained.

Rural fundamentalism, all other things being equal, also places a rancher in the "sell" group. This factor is identified as rural fundamentalism because of the relationship between the importance of ranching as a way of life, the fact that most of the ranchers' friends are cattlemen, and that the ranch owner lives on the ranch most of the year. Rural fundamentalism is defined as the attitude that the values and benefits associated with rural living are preferable to the values and benefits received from living in an urban environment. This factor, in conjunction with others, expresses the lack of desire for mobility and the strength of local ties common to rural agricultural persons, especially those older and less formally educated.

Rural Fundamentalism

Variable	Variable Abbreviation	Factor Loading
19	Rancher living on ranch	−.691
10	Ranching: good for children	−.641
23	Most friends cattlemen	−.614
13	Ranching: occupational choice	−.609
24	Way of life	−.586
11	Ranching: away from cities	−.482
26	All income from ranching	−.464
12	Ranching: fundamental values	−.379
8	Ranching: land for its own sake	−.275
20	Ranchers always lived on ranch	−.270

If a rancher has strong rural fundamental attitudes, his factor score is positive and:

1. he lives on his ranch most of the year.
2. he would feel that ranch ownership provides him a good place to raise children.
3. most of his friends are other cattlemen.
4. he would prefer ranching as a way of life for him in contrast to other occupations.
5. he would feel that ranching as a way of life is highly important to him.
6. he would feel that ranch ownership allows him to live away from cities at a place of his own.
7. he receives 100 percent of his income from ranching.
8. he would feel that ranch ownership allows him the opportunity of getting back to fundamental personal values.
9. he would feel that ranch ownership provides him the opportunity of owning land for its own sake.
10. he would have always lived on a ranch.

If an individual rancher displayed strong rural fundamentalistic attitudes, the discriminant analysis placed the ranch owner into the "sell" group. Such placement is contrary to the direction in which one might expect rural fundamentalistic attitudes to move a ranch owner; further explanation is needed.

By the time a third variable is needed in the discriminant analysis to classify a ranch owner into one group or the other, most ranchers have been already "correctly" classified on the basis of their land fundamentalism and conspicuous consumption/speculative attitude computed scores. Rural fundamentalism is the marginal variable used to separate overlapping groups. With the variable "the rancher lives on the ranch most of the year" being the most significant variable loading on the rural fundamentalism factor, the *net* effect of using the rural fundamentalism factor with a two-way classification of the dependent variable in the area of overlap is as follows:

1. A ranch owner who lives on the ranch most of the year and indicates that his ranch is presently for sale is likely to wish to sell his ranch, take the proceeds, and purchase a smaller ranch or home within the local area if a buyer can be found for his present ranch. These ranch owners generally have reasonably strong land fundamentalistic attitudes. In the final classification matrix where five ranch owners who indicate that their ranches are for sale are placed into the "keep" group, four of these ranchers desire to sell their ranches and relocate within the local rural area.

2. A person who does *not* live on the ranch most of the year and indicates that his ranch is presently not for sale likely will be willing to sell his ranch in the future since he is an absentee owner who tends to hold ranchland for land appreciation purposes. These ranch owners generally have reasonably strong conspicuous consumption/speculative attitudes and relatively weak land fundamentalism attitudes. However, they are strongly attracted by the rural area. In the final classification matrix where 13 ranch owners who indicate that their ranches are not presently for sale are placed into the "sell" group, nine of these ranchers are holding ranchland for purposes of land appreciation and six of these owners admit to speculating personally on the value of ranchland.

It is possible that the variables used to measure the rural fundamentalism factor are erroneous in their ability to specify the difference between living on the ranch most of the year and actually feeling that the rural way of life is preferable to any alternative way. However, the rural fundamentalism factor makes much sense if one reasons that the ranch owner desires to sell the ranch now, take the proceeds, and relocate within a rural area rather than move to an urban setting. Thus, rural fundamentalistic attitudes are found to be distinct from attitudes about land itself.

Implications for the Development of Rural Ranching Communities

In addition to the attitudinal factors listed above, the tenacity with which present ranch owners intend to keep their ranches is dependent upon the expectation that their children will go into ranching and upon the availability of outside sources of income. Eighty

percent of the ranch owners interviewed had outside jobs or income to help support the ranch (20 percent were nonprofessional or nonmanagerial jobs in the local community). Nearly 50 percent of the present ranch owners anticipate that their children will go into ranching and forego alternatives elsewhere; over a period of time, it is likely that the children will have to take outside jobs in the local area to maintain the ranch as a home and way of life. The median age of an Arizona rancher is nearly 60 years; if his children do not wish to take over the ranch, then by extension of this argument, the ranch will most likely be purchased by an investor who is not significantly dependent on the local community for his economic livelihood. Few ranchers are financially able to purchase additional property, even for purposes of obtaining economies of size. In addition, sufficient funds for ranch purchases are not likely to be available to participants in the local nonranching economy.

It is suggested that these facts, in combination with attitudes and goals of ranchers as discussed above, have implications for the survival and development of small towns in the West. The availability of jobs in the local area may well have stronger impact on the survival of current ranchers in the area than the ranchers have on the viability of the local community. Without a local job, a rancher may have to place his ranch on the market; future buyers presumably will not be as dependent on the local community for survival. Because of the rural fundamentalistic ethic, ranchers leaving the ranch attempt to remain in the local community where they compete for the relatively few available jobs.

It may be that the impact of ranching on the local economy is to be found more in terms of such dimensions as social stability and community leadership rather than in terms of significant economic benefits, since resources employed in cattle ranching are on the average underemployed. The implication is that the town keeps the present rancher going; one might be so extravagant as to suggest that ranching has no economic impact on the town and that an alternative use of the local rangelands, such as for recreation, might enhance the town's viability and growth. Economic satisficing attitudes on the part of surrounding ranchers are likely to produce the phenomenon that few, if any, economic development alternatives are seriously considered by community leaders, of whom these ranchers are a part.

The authors are currently planning a study in Arizona to examine these "impact" relationships in detail and to explain the viability or lack of viability of small rural communities and the ranches nearby. In doing so, the authors do not feel they can use aggregate methods such as input-output analysis or economic base analysis, traditionally used by economists in impact studies. Such methods are too mechanical and gloss over the complex social interrelationships so important in the business of small rural communities. The authors feel they must take an almost anthropological view of the communities' inhabitants in order to examine the detailed interactions involved. It is the interaction of the goals and attitudes of the people with specific types of economic opportunities that will explain the viability or decline of particular rural communities. It may be that some economic alternatives mesh with community attitudes and goals while some alternatives do not. More description of this interaction is needed before rational development plans with chances for acceptance can be suggested.

References

[1] BECKER, GARY, "Irrational Behavior and Economic Theory," *J. Polit. Econ.* 70:1–14, Feb. 1962.

[2] BOSTWICK, DON, "Financial Returns in Agriculture," *Am. J. Agr. Econ.*, 51:662–664, Aug. 1969.

[3] DICKERMAN, ALAN R., AND WILLIAM E. MARTIN, *Organization, Costs, and Returns for Arizona Cattle Ranches*, Department of Agricultural Economics File Report 67-6, University of Arizona, Sept. 1967, ditto.

[4] GUTTMAN, LOUIS, "Some Necessary Conditions for Common-Factor Analysis," *Psychometrika* 19:149–161, 1954.

[5] KATONA, GEORGE, "Rational Behavior and Economic Behavior," in *The Making of Decisions*, eds., William J. Gore and J. W. Dyson, New York, The Macmillan Company, 1964.

[6] MARTIN, WILLIAM E., AND JIMMIE R. GATZ, "Effects of Federal Income Taxes on Cattle-Ranch Prices," *Am. J. Agr. Econ.* 50:41–55, Feb. 1968.

[7] MARTIN, WILLIAM E., AND GENE L. JEFFERIES, "Relating Ranch Prices and Grazing Permit Values to Ranch Productivity," *J. Farm Econ.* 48:223–242, May 1966.

[8] MARTIN, WILLIAM E., AND ARTHUR H. SMITH, "The Southwestern Range Livestock Industry as a Sector of Modern Commercial Agriculture," *Forces Restructuring Production and Marketing in Commercial Agri-*

culture, Joint Proceedings of the Western Agricultural Economics Research Council, Tucson, Ariz., Nov. 1968.

[9] PAPANDREOU, ANDREAS G., "Some Basic Problems in the Theory of the Firm," in *A Survey of Contemporary Economics*, ed., Bernard F. Haley, Homewood, Ill., Richard D. Irwin, Inc., 1966.

[10] PEARSON, E. S., AND H. O. HARTLEY, "Percentage Points for the Distribution of Coefficients," Table 13, *Biometrika Tables for Statisticians*, Vol. 1, Cambridge, Cambridge University Press, 1954.

[11] Regional Research Project W-79, "Economic Analysis of Ranch and Ranch Management Decisions on Western Livestock Ranches," a cooperative effort of the Western Agricultural Experiment Stations, the Farm Production Economics Division of the Economic Research Service, and the Cooperative State Research Service, USDA. Budgets for all western states are on file in the library of the University of Nevada, Reno, 1968.

[12] RODEWALD, GORDON E., JR., AND DON BOSTWICK, "Goals of Range Livestock Cow-Calf Operators—Implications of Non-economic Goals in Economic Research," paper presented at the Western Agricultural Economics Association Annual Meeting, Squaw Valley, Calif., July 25–28, 1971.

[13] SIMON, H. A., *Models of Man*, New York, John Wiley & Sons, Inc., 1957.

[14] ———, "Decision-Making in Economics," *Am. Econ. Rev.* 49:253–283, June 1959.

[15] SMITH, ARTHUR H., "A Socioeconomic Analysis of the Goals and Attitudes of Arizona Cattle Ranchers," unpublished Ph.D. thesis, University of Arizona, Feb. 1971.

Appendix Table: Definition of variables used in the factor analysis

Variable	Definition	Variable	Definition
1	Current age of ranch owner (1968)	18	Number of animal units
2	Level of formal education of ranch owner	19	Ranch owner lives on ranch most of the year
3	Ranch owner expects his children to enter ranching	20	Ranch owner has always lived on a ranch
4	Ranch owner is a member of one or more cattle associations	21	Ranch owner presently has one or more relatives in ranching (excluding spouse)
5	Ranch owner is a member of one or more social organizations	22	Ranch owner has previously had one or more relatives in ranching
6	Ranch ownership provides him a basis for receiving tax advantages	23	Ranch owner's friends are mostly other cattlemen
7	Ranch ownership provides him an opportunity to speculate on ranchland	24	Importance of ranching as a way of life to the ranch owner
8	Ranch ownership provides an opportunity for the ranch owner to own land for its own sake	25	Ranch owner's original goal in owning his ranch was to make a living from beef production
9	Ranch ownership gives him status and prestige	26	100 percent of ranch owner's income is from ranching
10	Ranch ownership provides him a good place to raise children	27	Ranch is or is not making a profit
11	Ranch ownership allows him to live away from cities at a place of his own	28	Ranch owner believes that tax advantages can be obtained through ranch ownership whether he is receiving any or not
12	Ranch ownership allows him the opportunity to get back to fundamental personal values	29	Ranch owner's attitude about the low percent return on investment received from ranching
13	Ranch owner prefers ranching as a way of life for him compared to other occupations	30	Percent return on investment which would satisfy ranch owner
14	Ranch owner feels that land ownership permits him to feel closer to the earth	31	Ranch owner believes holding ranchland for land appreciation purposes is worthwhile
15	Ranch owner feels that land ownership causes him to hold more fundamental personal values	32	Ranch owner is actively speculating on the value of his ranchland
16	Ranch owner feels that land ownership gives him status and prestige	33	Ranch owner's intent to increase the size of his ranch
17	Number of deeded acres		

Short Articles and Notes

A Comparison of Annual Versus Average Optima For Fertilizer Experiments

John P. Doll

Seven annual production functions estimating corn response to applied nitrogen and plant population were derived for three locations in Missouri. Annual optima varied widely about input amounts that maximized average profits for the seven-year period but, except for extreme cases, resulting average profits differed little from the maximum average profit.

Seventeen years have passed since Heady and Pesek [9] published their pioneering article on corn-fertilizer response functions. At that time, they stated that although there was a "... long-standing knowledge of the need for improved knowledge of the crop-fertilizer marginal coefficients, relatively little progress has been made" [9, p. 466]. They attributed this lack of progress to the fact that fertilizer experiments had not been designed to estimate isoquants and isoclines. That is, rather than design experiments that included a wide range of fertilization rates spaced to provide useful estimates of the marginal products, agronomists selected only a few rates of fertilization and replicated them to obtain estimates of experimental error. The fertilization rates included in the experiment were, of course, based on *a priori* judgments by the agronomist; resulting yield differences were judged significant or insignificant depending upon the magnitude of the experimental error.

As an alternative, Heady and Pesek suggested that fertilization rates be increased, replications reduced, and a production surface be estimated using regression analysis. Economic optima could then be computed from the production surface, rather than selected from those rates stipulated beforehand by the experimenter.

The method of Heady and Pesek was immediately criticized by Hutton and Thorne [11], who approved of the original paper as a methodological exercise, but did not believe the method should be adopted for general use because (1) the loss from not using the optima or least cost combinations predicted by the regression equation was small and (2) the large experiments were "wasteful" of observations. This prompted a reply by Heady and Pesek [10] followed by a rejoinder by Hutton [12]. In spite of the misgivings of Hutton and Thorne, the methodology of Heady and Pesek continued to be used throughout the 1950's. Results of such experimentation were reported in two books sponsored by TVA [1, 2] and for Iowa, in Chapters 14 and 15 of Heady and Dillon [7].[1]

Unfortunately but understandably, the results reported in most of these publications were based only on one year's data. While the researchers were careful to point out the limitations of their data, such caveats could not suggest how the results might vary as data from additional years became available. Simply put, would additional years of experimental evidence support the need for exact optima as suggested by Heady and Pesek or would it serve to reinforce the objections of Hutton and Thorne?

The purpose of this note is to present an analysis of seven years of data from three experiments designed to estimate the response of corn yields to applied nitrogen and plant population. The analysis of the experiments should provide some information about the nature and magnitudes of the among-year variations in economic optima and least cost combinations as well as the sensitivity of aver-

John P. Doll *is a professor of economics at the University of Missouri, Columbia.*

[1] As one reviewer correctly suggested, the extent to which the Heady-Pesek methodology was actually adopted could only be demonstrated using definitive data on the number and type of experimental trials. Also, after the Heady-Pesek paper appeared, agronomists and statisticians suggested alternative experimental designs for estimating response surfaces. A discussion of alternative experimental designs for response surfaces may be found in Chapter 3 of [1] and Chapters 13 and 18 of [2]. Williams and Baker [14] have discussed this problem recently.

age profit over the seven years to alternative input levels.

The Data and Method Analysis

Experiments with corn were conducted at three sites in north and central Missouri: Saline, Grundy, and Boone Counties. Experimental methods and results are discussed in detail by Colyer and Kroth [4].[2] The same experimental procedure was duplicated at all sites over a seven-year period. Plot treatments were four levels of plant population (intended rates were 9,000, 13,000, 17,000, and 21,000 plants per acre) and seven nitrogen levels (0, 25, 50, 75, 100, and 200 pounds per acre). All treatment combinations were included and three replications were used. A final stalk count was taken at harvest and actual stand levels varied from 8,000 to as high as 24,000 plants per acre. To insure that nitrogen would be the only limiting nutrient, corrective treatments of P_2O and K_2O were applied in amounts determined by soil tests.

A quadratic production function with a linear interaction term was estimated from each set of data for each year. In all cases, the functions displayed positive signs on linear terms, negative signs on squared terms, and positive signs on the interaction terms.[3] The functions all yielded satisfactory coefficients of determination.

For each location, a profit function for each year was formed by multiplying the estimated production function by the price of corn per bushel and subtracting the cost of the nitrogen fertilizer and plant population. Thus, profit as used herein is actually total revenue net only of nitrogen and plant population costs. An average profit function for each experiment was obtained by averaging the seven annual profit functions. Initially, corn was priced at one dollar per bushel, nitrogen at 11 cents a pound, and plant population at one and a half cents per hundred. Profits were computed on an acre basis. The average profit functions were then analyzed in the general manner suggested by Heady and Pesek for single year analysis: least cost input combinations, isoprofit curves, and economic optima were obtained, only for the average function for the seven years rather than just one year.[4]

The data over the seven-year period also provide information about the among-year variability in yield response. Because the experiments are located on the same site each year, the errors associated with a given plot over time are undoubtedly serially correlated. However, an approximation of the among-year variance function for each experiment was obtained by computing the estimated variance in profit for a grid of points in the nitrogen-stand plane and regressing these variances on nitrogen and plant population.[5] The linear equations approximating the variance permit the computation of a "minimum variance" isocline. The problem is analogous to the classic problem in firm theory in which a given output must be produced at a minimum of cost. The estimated variance formula replaces the isocost line under pure competition and the estimated

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[2] Additional data were obtained directly from Professor Colyer. Experimental results for the Boone County experiment covered the time period from 1963–1969. Data for the other two experiments extended from 1962–1968.

[3] Square root functions did not adequately fit the data and often resulted in signs on coefficients that were not acceptable *a priori*. The Cobb-Douglas function was also ruled out on prior grounds; total yields did decrease at some point in most experiments. One quadratic function for Grundy County did demonstrate diminishing returns to both inputs but increasing returns when both inputs are increased along any isocline. It was almost linear and was included in the analysis because it does represent additional information. To my knowledge, there is no general response law, but for this set of experiments the quadratic function was found to be quite suitable.

[4] Averaging the annual functions assumes each annual function is equally likely and that the average function is certain. This assumption amounts to restricting the comparisons to the actual seven years that occurred. Broader inferences would be possible if the factors causing among-year variability could be studied. Problems involved in varying the "prior" probabilities are discussed elsewhere [5]. Bondavalli, Colyer, and Kroth [3] have discussed the problem of weather variability among the experimental sites. Price variability over the years is also ignored.

[5] The grid used varied for each experiment but was selected to cover points within the ridge lines and all annual optima. Thirty-six observations were used for Saline County, 35 for Grundy County, and 33 for Boone County. The resulting variance equations were

$$\text{Saline:}\quad \hat{V} = -156.46 + \underset{(0.24)}{1.97N} + \underset{(0.28)}{2.54S} \qquad R^2 = 0.90$$

$$\text{Grundy:}\quad \hat{V} = 85.28 + \underset{(0.21)}{0.60N} + \underset{(0.29)}{0.67S} \qquad R^2 = 0.60$$

$$\text{Boone:}\quad \hat{V} = -373.61 + \underset{(0.37)}{1.61N} + \underset{(0.45)}{5.13S} \qquad R^2 = 0.96$$

where $\hat{V}$ is the predicted variance, N is nitrogen per acre, and S is plant population per acre in hundreds. Standard errors are in the parentheses. These equations suggest direct estimation of the average function would be plagued by heteroscedasticity in addition to serial correlation.

coefficients of nitrogen and plant population replace the input prices. These coefficients are thus the "price paid" in terms of variance when inputs are increased. In each case, increasing plant population increases variance more than increasing nitrogen.

Results of the Analysis

Isoprofit curves, least cost, and minimum variance expansion paths for the average profit surfaces are presented in Figure 1. Annual optima for the experiments are contained in Table 1 and also plotted in Figure 1.[6] The isoclines drawn as solid lines in Figure 1 are ridge lines—they define the set of economically feasible combinations of nitrogen and plant population for the seven-year average profit function and converge at the point of maximum profit. The average isoprofit curves are labelled (AP). The dashed isoclines are either least cost expansion paths (LC) or minimum variance expansion paths (MV). The average optimal input amounts per acre and the resulting average profit per acre for the three experiments over the seven years are

	Nitrogen	Plant Population	Average Profit
Saline	106.6	15,304	$104.5
Grundy	159.6	16,593	112.0
Boone	116.3	14,920	100.4

How do the annual optima and the average profit resulting from them over the seven years differ from the average optima? That is, if the farmer were to choose one of the annual optima and use it every year, how much would he lose?[7] This can be determined by examining Figure 1 and Table 1. Of the 21 annual optima, 13 or 62 percent are outside the ridge lines of the average profit functions and thus not in the feasible economic set for the seven years. This is not surprising—if the factors causing year-to-year variations in the production functions are randomly and symmetrically distributed about their means, half of the optimum would be outside the ridge lines. More importantly, what are the losses in average profit from using the annual optima? For Saline County, five of the seven annual optima fall in the interior of the isoprofit curve for $100; for Grundy County, six of the seven annual optima are within the isoprofit curve for $100; and for Boone County, three of the seven annual optima result in expected profits within the isoprofit curve for $95. It is apparent from the study of Figure 1 and Table 1 that the annual optimal input amounts vary much more than the resulting average profits. For each county, much of the variation in average profits was caused by one low optimal rate that probably would not be used: 1963 for Saline, 1964 for Grundy, and 1963 for Boone County.

The insensitivity of average profit for the seven years to large variations in input amounts is suggested by the fact that the isoprofit curves for the average functions are ellipses with their major axes running in a southwest-northeast direction. Because the annual optima tend to scatter in the same direction, the resulting average profits do not vary widely.

The analysis shows that a wide range of nitrogen and plant population combinations can be used to achieve about the same average profit. While several of the annual optima could be equally suitable, there would be no point in using more than the average optimum or in fact in using any combination outside the ridge lines of the average profit functions (in the absence of forecast information). For example, the farm manager may wish to achieve a given level of average profit at a minimum of fertilization (and plant population) cost. If so, rather than choose a particular annual optimum, he could choose an input combination on the least cost expansion path that would return the same average profit. The least cost expansion paths are graphed in Figure 1 (and labelled LC) and the least cost combinations corresponding to each annual optima are given in Table 2. For Saline and Grundy Counties, savings in fertilization costs up to $10 an acre can be achieved by using the least cost combinations. In Saline County, for example, the farm manager could use the 1968 optima of 137 pounds of nitrogen and 19,000 plants per acre at a cost of $18 or he could obtain the same average yield using 56 pounds of nitrogen and 14,000 plants at a cost of $8 an acre. A farmer planting 100 acres would require $1,000 more operating capital each year to use the 1968 optima even though his profit over the seven years would be the same (net of

[6] Annual optima were restricted to the input limits of the experimental data. Optima that fell outside the limits were lowered to the highest point on the expansion path within the experimental limits.

[7] Or if the experiment were conducted for only one year, how useful would the resulting optimum be? Of course, the optimum for each year is subject to the within-year variability. Confidence regions for annual optima would be of interest here and could be derived. See Heady, Jacobson, Madden, and Freeman [8].

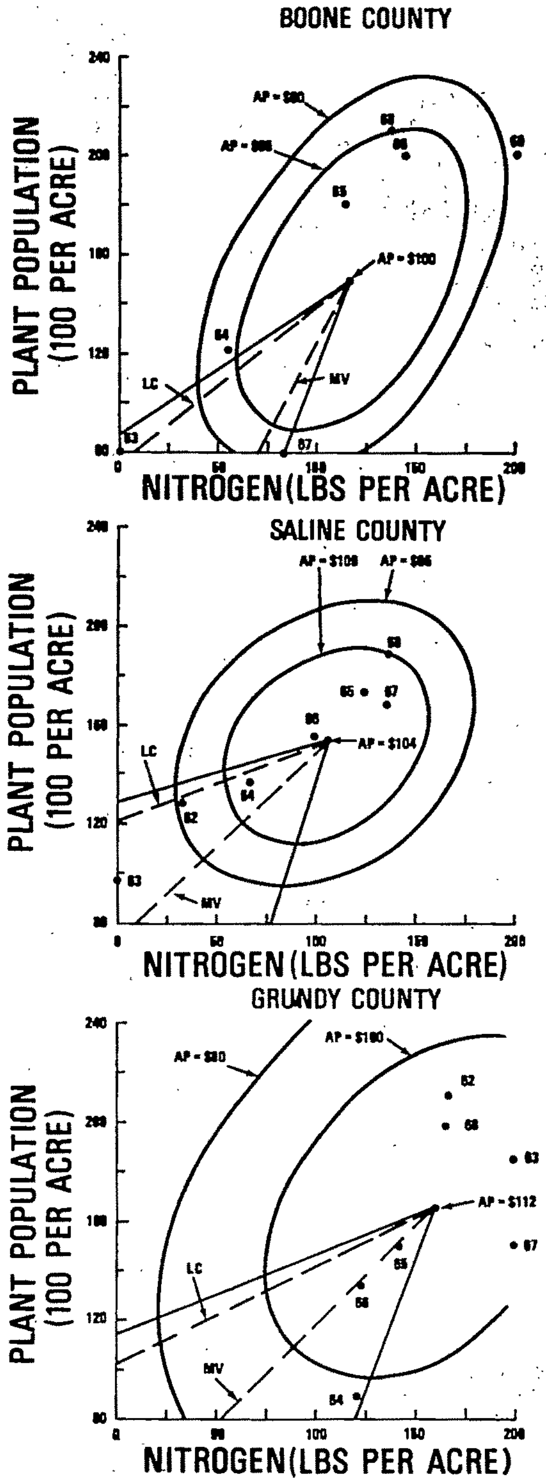

Figure 1. Isoprofit curves, annual and average optima, ridge lines and expansion paths for the three average profit functions (per acre)

Table 1. Economic optima for seven years of corn experiments in three Missouri counties (per acre)

County	Year	Applied nitrogen (lbs.)	Plant population	Profit for year computed*	Average profit over seven years*
	62	31.9	12,836	$96.2	$95.6
	63	0	9,736	73.7	83.7
	64	67.4	13,777	110.8	102.0
Saline	65	125.5	17,245	140.5	103.2
	66	99.7	15,404	108.9	104.4
	67	136.4	16,866	119.3	102.8
	68	136.6	18,905	109.2	100.5
	62	166.7	21,000	$115.2	$107.1
	63	200.0	18,476	128.9	109.3
	64	119.1	8,976	108.6	98.1
Grundy	65	142.1	14,963	109.1	111.3
	66	122.9	13,356	124.4	108.7
	67	200.0	15,084	105.7	107.2
	68	166.6	19,810	144.1	109.5
	63	0	8,000	$90.6	$77.2
	64	55.0	12,162	98.6	93.9
	65	129.4	18,129	135.2	98.8
Boone	66	144.2	20,857	107.2	95.0
	67	82.9	8,000	95.3	93.0
	68	138.9	21,000	145.7	94.6
	69	200.0	20,303	81.2	88.2

* Prices used were $1.00 per bushel of corn, 11 cents a pound for nitrogen, and 15 cents per thousand plants. Profit is net of nitrogen and plant population costs only.

interest charges). In Boone County, the savings in operating costs included $10 per acre at two rates and $20 for one extreme rate.

The farm manager may consider changes in operating capital insignificant and instead

Table 2. Least cost combinations of applied nitrogen and plant population that return same average profit from corn as annual optima (per acre)

County	Year	Applied nitrogen (lbs.)	Plant population	Cost of least cost combination
	62	31.6 (−0.3)*	13,097 (+261)*	$5.44 (−$0.00)*
	63	0 (0.0)	9,736 (0)	1.46 (0.00)
	64	66.6 (−0.8)	14,120 (+343)	9.44 (− 0.04)
Saline	65	78.6 (−46.9)	14,473 (−2,772)	10.82 (− 5.57)
	66	99.0 (−0.7)	15,069 (−335)	13.15 (− 0.13)
	67	74.5 (−61.9)	14,353 (−2,513)	10.34 (− 7.18)
	68	56.4 (−80.2)	13,822 (−5,083)	8.28 (− 9.58)
	62	105.2 (−61.5)	14,430 (−6,570)	$13.74 (−$7.75)
	63	118.9 (−81.1)	14,971 (−3,505)	15.33 (− 9.45)
	64	68.4 (−50.7)	12,973 (+3,997)	9.47 (− 4.98)
Grundy	65	137.7 (− 4.4)	15,711 (+748)	17.50 (− 0.37)
	66	114.5 (−8.4)	14,795 (+1,439)	14.81 (− 0.71)
	67	105.5 (−94.5)	14,442 (−642)	13.78 (−10.49)
	68	120.4 (−46.2)	15,030 (−4,780)	15.50 (− 5.80)
	63	0 (0)	8,000 (0)	$1.20 ($0)
	64	55.2 (+0.2)	11,031 (−1,131)	7.73 (− 0.15)
	65	85.7 (−43.7)	12,981 (−5,148)	11.37 (− 5.58)
Boone	66	60.4 (−83.8)	11,362 (−9,495)	8.35 (−10.64)
	67	51.1 (−31.8)	10,774 (+2,774)	7.24 (− 3.91)
	68	58.3 (−80.6)	11,234 (−9,766)	8.10 (−10.33)
	69	32.4 (−167.6)	9,578 (−10,725)	5.00 (−20.04)

* Departure from quantity or cost of annual optima.

Table 3. Minimum variance combinations of applied nitrogen and plant population that return same average profit from corn as annual optima (per acre)

County	Year	Applied nitrogen (lbs.)	Plant population	Predicted variance
	62	45.4 (+13.5)*	10,771 (−2,065)*	207 (−26)*
	63	12.8 (+12.8)	8,356 (−1,380)	81 (−10)
	64	74.0 (+6.6)	12,888 (−889)	317 (−9)
Saline	65	83.7 (−41.8)	13,609 (−3,636)	354 (−331)
	66	100.5 (+0.8)	14,849 (−555)	419 (−12)
	67	80.4 (−56.0)	13,359 (−3,507)	341 (−200)
	68	65.5 (−71.1)	12,261 (−6,644)	284 (−309)
	62	115.1 (−51.6)	13,020 (−7,980)	241 (−85)
	63	125.0 (−75.0)	13,815 (−4,661)	253 (−76)
	64	82.0 (−37.1)	10,357 (+1,381)	204 (−13)
Grundy	65	140.5 (−1.6)	15,060 (+97)	270 (−1)
	66	121.2 (−1.7)	13,504 (+148)	248 (0)
	67	113.6 (−86.4)	12,899 (−2,185)	240 (−78)
	68	126.3 (−40.3)	13,919 (−5,891)	254 (−52)
	63	0 (0)	8,000 (0)	36 (0)
	64	74.4 (+19.4)	11,217 (−945)	321 (−18)
	65	95.4 (−34.0)	11,762 (−6,367)	383 (−382)
Boone	66	77.8 (−66.4)	9,102 (−11,755)	219 (−709)
	67	71.6 (−11.3)	10,788 (+2,788)	295 (−125)
	68	76.6 (−62.3)	8,918 (−12,082)	207 (−720)
	69	37.3 (−162.7)	8,000 (−12,303)	97 (−893)

* Departure from quantity or variance at annual optima.

prefer to choose an input combination that minimizes the variance of a given level of average profit. The minimum variance expansion paths are also graphed in Figure 1 (and labelled MV) and the minimum variance combinations of inputs corresponding to each annual optima are contained in Table 3. Again, minimum variance combinations involve the use of lower input levels than do the annual optima. When compared to least cost combinations, the minimum variance combinations for all three experiments require the use of higher rates of nitrogen and lower rates of plant population. While the price of plant population is low relative to the price of nitrogen, plant population "costs" more in terms of variance—higher stand rates are riskier. Thus, the minimum variance isoclines are to the right of and more steeply sloped than the least cost isoclines.[8]

Two Additional Analyses

Heady and Pesek [9] pointed out that some farmers may not use the optimum because of capital limitations. In such cases, the recommended rate would be a point on the expansion path but below the optimal rates. The expansion paths for the seven years and the average

[8] An alternative method of analyzing the effects of the variance of average profits would be to use the E-V analysis described in Chapters 4 and 8 of Halter and Dean [6]. Their analysis is not pursued here in the interests of brevity.

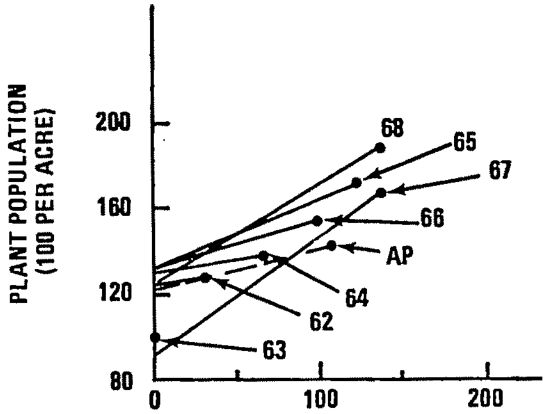

Figure 2. Expansion paths for annual profit functions and the average function, Saline County (per acre)

profit function for Saline County are shown in Figure 2. (Results for the other experiments are similar and will not be shown.) The expansion paths for individual years vary about the expansion path for the average profit function (above 12,000 plants per acre), suggesting that recommendations for rates lower than the optima would be subject to the same type of scatter as the annual optima, while the average isoprofit curves in Figure 1 imply the resulting profit differential would not be large. In fact, the capital limitation could restrict the farmer to fertilization rates that approach the average optimum or fall close to the least cost isocline for the average function.

The effect of changing prices may be found by expressing the optimum amount of nitrogen and plant population for the seven-year average profit function parametrically as a function of the three prices. When this is done, the average optimum amounts turn out to be linear functions of the input prices and nonlinear functions of corn price.

The price of plant population is very small and its variations are not important. Of the remaining two prices, corn prices are most likely to vary. Therefore, for the Saline County experiment, graphs of the optimum input amounts as a function of corn price and average profit as a function of corn price are shown in Figure. 3. The functions plotted were derived for a nitrogen price of 11 cents a pound and a plant population price of one and a half cents per hundred.

For corn prices around one dollar, optimum input amounts are not extremely sensitive to corn price. For corn prices of \$.90, \$1.00, and \$1.10, average optimal nitrogen is 103, 107, and 110 pounds per acre; for the same prices, average optimal plant population is 15,000, 15,300, and 15,400. Decreases do not begin to cause large changes until corn prices drop to \$0.80 (when optimal nitrogen begins to fall more rapidly) and \$0.50 (for plant population). Expected profits increase at a slightly increasing rate; input usage approaches asymptotic limits (the input amounts that maximize average yield) as corn prices increase.

Because the average optima are linear functions of nitrogen price, the curves in Figure 3 shift downward (upward) as nitrogen price increases (decreases). For a corn price of one dollar and a plant population price of one and a half cents per hundred, a penny increase of nitrogen price would reduce the average optimum by 3.2 pounds; thus, a three-cent change in either direction would shift the optima up or down about 10 pounds an acre. At the same prices, a one-cent change in the price of nitrogen would cause optimal plant population amounts to decrease by a mere 70 plants and reduce average profit by \$1.1 per acre.[9]

The price of nitrogen per pound in Missouri could drop as low as six cents a pound, depending on the material used and the method of application. At six cents a pound, other prices constant, average profit increases to \$110.1 per

[9] A further analysis, again not pursued in the interest of brevity, would include the derivation of short-run corn supply functions and input demand functions as demonstrated by Tweeten and Heady [13].

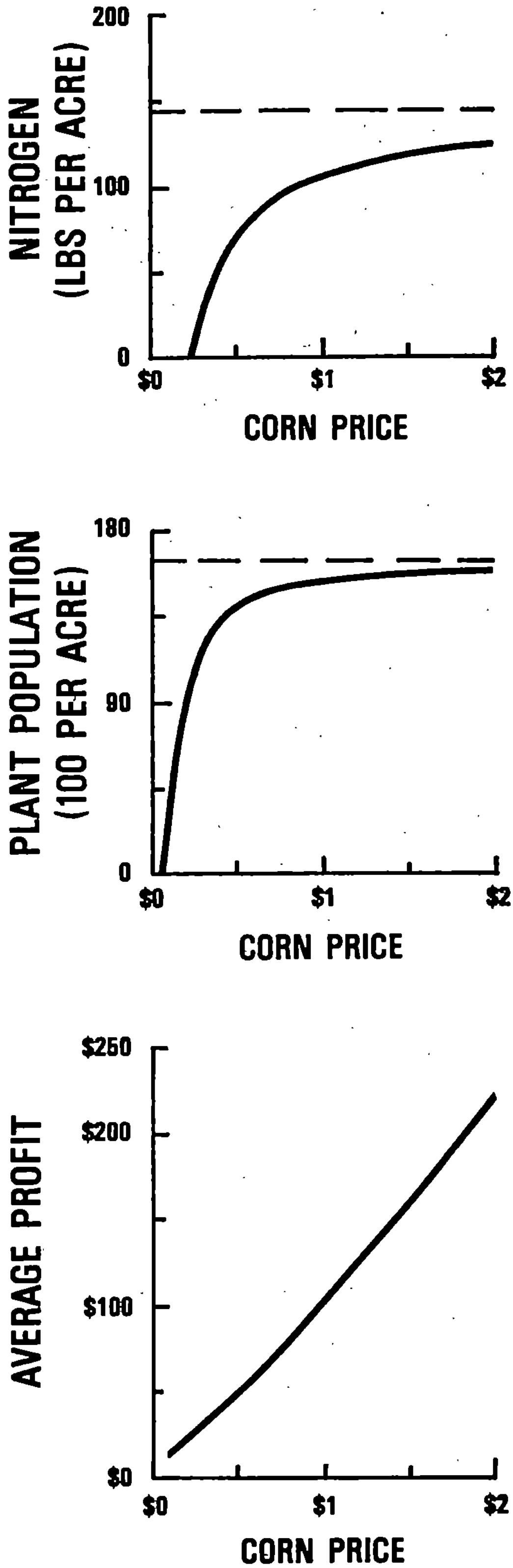

Figure 3. Optimal nitrogen and plant population for the seven-year average profit function expressed as a function of corn price, Saline County (per acre)

acre. Thus, within limits, the cost of nitrogen is as important as the amount applied.

Conclusions

Five of the annual optima resulted in average profits that fell within a range of $3.9 per acre for Saline County; six fell within a range of $4.2 for Grundy County; and five fell within a range of $5.8 for Boone County. If these average profit differentials can be termed not significant, then the results suggest that average profits are not extremely sensitive to the selection of exact economic optima. Annual optimal fertilizer amounts were found to vary significantly from year-to-year but resulting expected profits did not. Least cost combinations or minimum variance combinations for the average functions utilized much smaller input amounts than most annual optima. Thus, the farmer could generally be more conservative than the use of most annual optima would suggest but still earn equivalent profits. This finding is significant, given the present concerns about nitrate pollution.

Ex post, it might be argued for this example that the large experiments needed to estimate the production surfaces were not necessary. But because of the nature of the Heady-Pesek methodology, the wide range of input amounts included will always be reduced to a single point (the optima) or set of points (the expansion path). While the input amounts along the expansion path are not known ex ante, the results for the three experiments presented here indicated that average profits were not sensitive to even fairly wide variations in input amounts. Thus, the economic optima for the expected profit functions could have been obtained using fewer observations contained primarily within the ridge lines and along the expansion paths of the average profit functions. This suggests that an experienced team of agronomists and agricultural economists should possess sufficient prior knowledge to come reasonably close to delineating the area of economic relevance. Unfortunately, intuition can be quite misleading. Perhaps the optimal allocation of fertilizer research funds would involve the use of a few large Heady-Pesek experiments to delineate generally the area of economic relevance while utilizing smaller experiments containing a number of carefully chosen input combinations to obtain estimates of variations over space and time. Thus, for the set of experiments analyzed here, the Hutton-Thorne argument must be granted considerable credence.

References

[1] BAUM, E. L., EARL O. HEADY, AND JOHN BLACKMORE, eds., *Methodological Procedures in the Economic Analysis of Fertilizer Use Data*, Ames, Iowa State College Press, 1956.

[2] BAUM, E. L., EARL O. HEADY, JOHN T. PESEK, AND CLIFFORD G. HILDRETH, eds., *Economic and Technical Analysis of Fertilizer Innovations and Resource Use*, Ames, Iowa State College Press, 1957.

[3] BONDAVALLI, BRUNO, DALE COLYER, AND EARL M. KROTH, "Effects of Weather, Nitrogen and Population on Corn Yield Response," *Agron. J.* 62:669–672, Sept.–Oct. 1970.

[4] COLYER, DALE, AND EARL M. KROTH, "Corn Yield Response and Economic Optima for Nitrogen Treatments and Plant Population Over a Seven-Year Period," *Agron. J.* 60:524–529, Sept.–Oct. 1968.

[5] DOLL, JOHN P., "Obtaining Preliminary Bayesian Estimates of the Value of a Weather Forecast," *Am. J. Agr. Econ.* 53:651–655, Nov. 1971.

[6] HALTER, A. N., AND G. W. DEAN, *Decisions Under Uncertainty*, Cincinnati, South-Western Publishing Company, 1971.

[7] HEADY, EARL O., AND JOHN L. DILLON, *Agricultural Production Functions*, Ames, Iowa State University Press, 1961.

[8] HEADY, EARL O., N. L. JACOBSON, J. PATRICK MADDEN, AND A. E. FREEMAN, *Milk Production Functions in Relation to Feed Inputs, Cow Characteristics and Environmental Conditions*, Iowa Agr. Exp. Sta. Res. Bull. 529, July 1964.

[9] HEADY, EARL O., AND JOHN PESEK, "A Fertilizer Production Surface with Specification of Economic Optima for Corn Grown on Calcareous Ida Silt Loam," *J. Farm Econ.* 36:466–482, Aug. 1954.

[10] ———, "Hutton and Thorne on Isoclines: A Reply," *J. Farm Econ.* 37:363–368, May 1955.

[11] HUTTON, R. F., AND D. W. THORNE, "Review Notes on the Heady-Pesek Fertilizer Production Surface," *J. Farm Econ.* 37:117–119, Feb. 1955.

[12] HUTTON, ROBERT F., "Further Comment on the Heady-Pesek Fertilizer Production Function," *J. Farm Econ.* 37:566–568, Aug. 1955.

[13] TWEETEN, LUTHER G., AND EARL O. HEADY, *Short-Run Corn Supply and Fertilizer Demand Functions Based on Production Functions Derived from Experimental Data; a Static Analysis*, Iowa Agr. Exp. Sta. Res. Bull. 507, June 1962.

[14] WILLIAMS, R. J., AND J. R. BAKER, "A Comparison of Response Surface and Factorial Designs in Agricultural Research," *Rev. Market. & Agr. Econ.* 36:165–177, Dec. 1968.

The Generalized Power Production Function*

Alain de Janvry

The generalized power production function includes as special cases the Cobb-Douglas, the Transcendental, and the Cobb-Douglas with variable returns to scale. It can be estimated by ordinary least squares without simultaneous equation bias under the behavioral assumption of maximization of expected profits.

The generalized power production function (GPPF) includes as special cases the Cobb-Douglas, the Transcendental [6], and the Cobb-Douglas with variable returns to scale [10]. It allows for nonhomogeneity and also for variability of the returns to scale, marginal productivities, elasticities of production, marginal rates of substitution, and elasticities of substitution. The gain in generality relative to the Cobb-Douglas and Transcendental is obtained at no cost in terms of difficulty of empirical analysis since all GPPF's can be estimated by ordinary least squares.

The distinguishing features of the GPPF are analyzed, and an example which permits a better specification than the Cobb-Douglas and Transcendental is discussed. Proof is then given that, under the behavioral assumption of maximization of expected profits as in Zellner, Kmenta, and Drèze [11], direct estimation of the production function from cross-section data on firms is always free from simultaneous equation bias, whatever the functional form specified. This result, hence, extends to the GPPF.

Properties

The GPPF can be written as

$$Y = A \prod_{k=1}^{K} X_k^{f_k(X)} e^{g(X)}$$

where $f_k(X)$ and $g(X)$ are polynomials of any degree in the arguments of the K-dimensional input vector X. Special cases of this class of functions are for

$g(X)=0$ and $f_k(X)=\alpha_k$ for all k, the Cobb-Douglas

$g(X)=\sum_k \gamma_k X_k$ and $f_k(X)=\alpha_k$ for all k, the Transcendental

$g(X)=0$ and $f_k(X)$ homogeneous of degree zero in X for all k, the Cobb-Douglas with variable returns to scale

$g(X)=0$, the Cobb-Douglas with variable elasticities of production.

The marginal productivity of factor X_i is

$$\frac{\partial Y}{\partial X_i} = Y\left[\frac{f_i(X)}{X_i} + \frac{\partial g(X)}{\partial X_i} + \sum_{k=1}^{K} \frac{\partial f_k(X)}{\partial X_i} \log X_k\right].$$

It reduces to $Y(\alpha_i/X_i)$ in the case of the Cobb-Douglas and to $Y[(\alpha_i/X_i)+\gamma_i]$ with the Transcendental. It can assume positive, zero, or negative values according to the specification of the polynomials $f_i(X)$ and $g(X)$ and to the values of the X's. Thus, the GPPF can describe all three stages of production provided $g(X)\neq 0$.

The function is homogeneous if and only if the polynomials $f_k(X)$, $k=1, \cdots, K$, and $g(X)$ are homogeneous of degree zero in X. In this case, Carlson's function coefficient [2, p. 17] is

$$\epsilon = \frac{dY}{mY} = \sum_k f_k(X)$$

where $m=dX_k/X_k$, all k. The degree of homogeneity of the GPPF is ϵ, and the function will exhibit variable returns to scale unless all $f_k(X)$ are independent of X, which is, for example, the Cobb-Douglas case. Following Carlson [2] and Gates [4], the economic region of production is defined by the set of values of the X's that satisfies

$$0 \leq \sum_k f_k(X) \leq 1.$$

For simplicity, consider the special two-inputs case

$$Y = AX_1^{\alpha_1+\beta_1 X_2} X_2^{\alpha_2} e^{\gamma_1 X_1}.$$

It is a Cobb-Douglas if $\beta_1=\gamma_1=0$, a Transcendental if $\beta_1=0$, and a Cobb-Douglas with variable elasticities of production if $\gamma_1=0$.

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Alain de Janvry *is assistant professor of agricultural economics at the University of California, Berkeley.*

The marginal productivities are

$$\frac{\partial Y}{\partial X_1} = \frac{Y}{X_1}(\alpha_1 + \beta_1 X_2 + \gamma_1 X_1),$$

$$\frac{\partial Y}{\partial X_2} = \frac{Y}{X_2}(\alpha_2 + \beta_1 X_2 \log X_1).$$

Hence, the marginal productivity of X_1 is zero for $X_1 = -(\alpha_1+\beta_1 X_2)/\gamma_1$. It is maximum for

$$\frac{\partial^2 Y}{\partial X_1^2} = \frac{Y}{X_1^2}[(\alpha_1 + \beta_1 X_2 + \gamma_1 X_1)^2 - (\alpha_1 + \beta_1 X_2)] = 0;$$

that is, for

$$X_1 = -\frac{1}{\gamma_1}(\alpha_1 + \beta_1 X_2 \pm \sqrt{\alpha_1 + \beta_1 X_2}).$$

Consider the case where $\gamma_1 < 0$[1] and $\alpha_1+\beta_1 X_2 > 1$.[2] The inflection point that is obtained on the range of X_1 where it has positive marginal productivities corresponds to the negative sign of the square root. Hence, X_1 will have a positive and decreasing marginal productivity in the interval

$$-\frac{1}{\gamma_1}(\alpha_1 + \beta_1 X_2 - \sqrt{\alpha_1 + \beta_1 X_2}) < X_1 < -\frac{1}{\gamma_1}(\alpha_1 + \beta_1 X_2).$$

This interval is a function of X_2. Hence, (1) if $\beta_1 > 0$, as X_2 increases, the interval $(0, -[\alpha_1+\beta_1 X_2/\gamma_1])$ over which X_1 has a positive marginal productivity expands and so does the interval of variation of X_1 over which $MP_1 > 0$ and $\partial MP_1/\partial X_1 < 0$; and (2) if $\beta_1 < 0$, as X_2 increases, the interval of variation of X_1 over which it has positive marginal productivity decreases, and so does the interval over which $MP_1 > 0$ and $\partial MP_1/\partial X_1 < 0$. Once X_2 exceeds the critical level

$$X_2 = -\frac{1}{\beta_1}(\alpha_1 + \gamma_1 X_1),$$

X_1 has a negative marginal productivity.

When $\gamma_1 = 0$, the function reduces to a Cobb-Douglas with variable elasticities of production that can describe only one stage of production. The marginal productivity of X_1 will be positive for $X_2 > -\alpha_1/\beta_1$. For $\alpha_1 > 0$, (1) if $\beta_1 > 0$, $MP_1 > 0$ will always be satisfied; and (2) if $\beta_1 < 0$, for $MP_1 > 0$, $X_2 < |\alpha_1/\beta_1|$ is needed. If X_2 exceeds this maximum, X_1 has a negative marginal productivity over its whole range of variation.

The degree of *substitutability* between inputs is affected by the value of the parameters α_1, α_2, and β_1 and by the levels of X_1 and X_2. It is characterized by the elasticity of substitution, σ, which can be calculated using Allen's formula [1, p. 342]

$$\sigma = -\frac{f_1 f_2 (X_1 f_1 + X_2 f_2)}{X_1 X_2 (f_2^2 f_{11} - 2 f_1 f_2 f_{12} + f_1^2 f_{22})}$$

where $f_i = \partial Y/\partial X_i$ and $f_{ij} = \partial^2 Y/\partial X_i \partial X_j$. Denoting by $a = \alpha_1+\beta_1 X_2$ and $b = \alpha_2+\beta_1 X_2 \log X_1$, $f_{11} = (Y/X_1^2)a(a-1)$, $f_{22} = (Y/X_2^2)(b^2-\alpha_2)$, and $f_{12} = (Y/X_1X_2)\ (ab+\beta_1 X_2)$ are obtained. The elasticity of substitution is hence

$$\sigma = \frac{b(a+b)}{b^2 + a\alpha_2 + 2b\beta_1 X_2}.$$

For $\beta_1 = 0$, this is the classical Cobb-Douglas case and $\sigma = 1$. Otherwise, σ is a variable parameter. To see the impact of β_1 on the elasticity of substitution relative to the Cobb-Douglas case, rewrite

$$\sigma = \frac{\alpha_2(\alpha_1 + \alpha_2) + \Delta N(\sigma)}{\alpha_2(\alpha_1 + \alpha_2) + \Delta D(\sigma)}$$

where $\Delta N(\sigma)$ and $\Delta D(\sigma)$ represent the changes in the numerator and denominator of σ, respectively, due to the introduction of $\beta_1 X_2$ in the exponent of X_1. To see whether σ is greater or smaller than one, $\Delta N(\sigma)$ should be compared to $\Delta D(\sigma)$. Then,

$$\Delta N(\sigma) = \alpha_2\beta_1 X_2(1 + 2\log X_1) + \beta_1 X_2 \log X_1(\alpha_1 + \beta_1 X_2 + \beta_1 X_2 \log X_1)$$

and

$$\Delta D(\sigma) = \alpha_2\beta_1 X_2(3 + 2\log X_1) + \beta_1 X_2 \log X_1(2\beta_1 X_2 + \beta_1 X_2 \log X_1).$$

[1] With $\gamma_1 > 0$, the production function would increase at a decreasing rate until the first inflection point and then at an increasing rate—an uninteresting situation. For $\gamma_1 = 0$, the function reduces to a Cobb-Douglas with variable elasticities of production, a case we shall consider later.

[2] For $\alpha_1+\beta_1 X_2 > 1$, the inflection points occur over the range of positive X_1's. For $\alpha_1+\beta_1 X_2 = 1$, the inflection point where $MP_1 > 0$ is obtained at $X_1 = 0$. And for $\alpha_1+\beta_1 X_2 < 1$, there are no inflection points.

Hence, $\Delta N(\sigma)=\Delta D(\sigma)$ if $\alpha_1 \log X_1 = 2\alpha_2 + \beta_1 X_2 \log X_1$, that is, if

$$\beta_1 = \frac{\alpha_1 \log X_1 - 2\alpha_2}{X_2 \log X_1}.$$

When β_1 and X_2 decrease, σ increases. In particular, for $\beta_1<0$, σ decreases when X_2 increases; X_1 and X_2 are poorer substitutes the higher the level of X_2.

The *marginal productivity* schedule of X_1 may shift upward or downward as X_2 increases. Obviously, if $\alpha_1, \alpha_2, \beta_1>0$, MP_1 will shift upward as X_2 increases, just as in the pure Cobb-Douglas case. On the other hand, when $\beta_1<0$, increases in X_2 tend to shift MP_1 downward through the effect on $X_1^{\alpha_1+\beta_1 X_2}$ and upward through the direct effect $X_2^{\alpha_2}$. The net effect will depend upon the relative sizes of α_1, α_2, and β_1 and upon the level of X_1 and X_2. With

$$MP_1 = AX_1^{\alpha_1+\beta_1 X_2 - 1} X_2^{\alpha_2}(\alpha_1 + \beta_1 X_2),$$

the change in MP_1 due to a change in the level of X_2 is

$$\frac{\partial MP_1}{\partial X_2} = \frac{Y}{X_1 X_2}\left[(\beta_1^2 \log X_1)X_2^2 + \beta_1(\alpha_1 \log X_1 + \alpha_2 + 1)X_2 + \alpha_1\alpha_2\right].$$

For $\alpha_1, \alpha_2, \beta_1>0$, $\partial MP_1/\partial X_2>0$.

For $\beta_1<0$, $\partial MP_1/\partial X_2<0$ will be obtained inside the interval

$$X_2 = \frac{-(\alpha_1 \log X_1 + \alpha_2 + 1)}{2\beta_1 \log X_1} \pm \frac{\sqrt{(\alpha_1 \log X_1 + \alpha_2 + 1)^2 - 4\alpha_1\alpha_2 \log X_1}}{2\beta_1 \log X_1}.$$

An example where such a specification is useful is the case of fertilizer response where Y would denote yield, X_1 fertilizer, and X_2 natural fertility of the soil. Because soil fertility decreases the intensity of fertilizer response, $\beta_1<0$. Then, for soil fertility above a certain threshold $X_2=|\alpha_1/\beta_1|$, fertilizer has a negative marginal productivity. For $X_2<|\alpha_1/\beta_1|$, increases in soil fertility may shift downward the marginal productivity of fertilizer and lead to lower optimal doses of fertilizer for given prices. A full empirical application of the GPPF in this context is given in [3].

Estimation

Let the stochastic form of the GPPF be

$$Y = A\prod_{k=1}^{K} X_k^{f_k(X)} e^{g(X)} e^{u_0},\ E(e^{u_0}) = \mu.^3$$

Estimation from experimental data can be performed with ordinary least squares since the function linearizes in its logarithmic form, and there is no simultaneity bias between inputs and outputs.

It is well known that a simultaneity bias may be incurred when working cross sectionally with firm data [7]. On the other hand, Zellner *et al.* [11] have shown that, if certain reasonable assumptions are satisfied, the bias disappears in the estimation of the Cobb-Douglas when the economic model is specified in terms of maximization of expected profits. Recently, Hodges [8] extended this result to the CES. Through a very general proof it will be shown that maximization of expected profits eliminates the simultaneity bias in the estimation of all production functions and, hence, in particular, of the GPPF.

Consider the general class of stochastic production functions

$$(1) \qquad Y = f(X)e^{u_0},\ E(e^{u_0}) = \mu.$$

The residual u_0 represents both the influence of stochastic noncontrollable inputs and of the technical efficiency of management. Under conditions of pure competition, the objective of each firm is to maximize expected profits

$$\max E(\Pi) = PE(Y) - \sum_{i=1}^{K} P_i X_i - C$$

where P and P_i are expected prices of product and factors, respectively, and C denotes fixed costs. Prices are either known with certainty or stochastic but independent of the disturbance term in the production function. Expected output is

$$E(Y) = f(X)\mu.$$

The marginal expected productivity of factor X_i can be written as

$$f_i(X)\mu \equiv f(X)g_i(X)\mu = Ye^{-u_0}g_i(X)\mu$$

[3] This specification of the expected value of e^{u_0}, $E(e^{u_0})=\mu$, is in particular obtained under the normality assumption $u_0 \sim N(0, \sigma_{00})$ since e^{u_0} is then distributed as a lognormal with expected value $\mu = e^{1/2\sigma_{00}}$.

where $g_i(X)$ always exists and is defined so that the first equality be identically satisfied. In logarithmic form, the structural model is given by the set of $K+1$ equations

$$\log Y = \log f(X) + u_o$$
$$\log Y = k_i - \log g_i(X) + u_o + u_{1i}, \quad i = 1, \cdots, K$$

where $k_i = \log(P_i/P\mu)$ is constant cross-sectionally among firms. The residual u_o has been "transmitted" additively from the production function to the decision functions. Following Zellner *et al.* [11], additional disturbance terms u_{1i} have been introduced in the decision functions to represent economic inefficiencies in the process of profit maximization and also errors in the formation of price expectations. From their definition, the u_{1i}'s can reasonably be expected to be independent of u_o.

The pseudo-reduced form of the model is[4]

$$\log Y = H(k, u_1) + u_o$$
$$\log f(X) + \log g_i(X) = k_i + u_{1i}, \; i = 1, \cdots, K$$

where k and u_1 are vectors of elements k_i and u_{1i}, $i=1, \cdots, K$. The optimal input levels are not a function of u_o. If, furthermore, u_o is independent of u_1, consistent estimates of the parameters of the production function are obtained directly by least squares in the logarithmic form of that function. When $f(X)$ is a GPPF, ordinary least squares can be used. When $f(X)$ does not linearize under a logarithmic transformation—as, for example, with a CES—nonlinear least squares or least squares applied to a linear approximation of the function, as in Kmenta [9], must be used. As noted by Goldberger [5] for the Cobb-Douglas case, in all these functions $f(X)$ is a predictor of the conditional median, while predictions of the conditional mean would be obtained from $f(X)\mu$.

A similar result obtains in the estimation of the general class of stochastic production functions

$$(2) \qquad Y = f(X) + u_o, \quad E(u_o) = 0.$$

Define again a function $g_i(X)$ so that the marginal expected productivity of X_i can be written identically as

$$f_i(X) \equiv f(X)g_i(X) = (Y - u_o)g_i(X).$$

The structural form of the model is then

$$Y = f(X) + u_o$$
$$Y = k_i/g_i(X) + u_o + u_1 \quad \text{where} \quad k_i = P_i/P.$$

As before, transmission of u_o to the decision functions eliminates the dependence between X and u_o. If u_o and u_1 are uncorrelated, consistent estimates of the parameters of the production function are obtained by direct estimation in (2).

In conclusion it has been found that maximization of expected profits according to Zellner *et al.* [11] with all stochastic production functions (1) or (2) permits consistent estimation of the production function parameters from single equation fits of the production function.

[4] Pseudo in the sense that an explicit solution for each X_i is not given.

References

[1] ALLEN, R. G. D., *Mathematical Analysis for Economists*, New York, The Macmillan Co., 1966.

[2] CARLSON, SUNE, *A Study on the Pure Theory of Production*, New York, Augustus M. Kelley Publishers, 1969.

[3] DE JANVRY, ALAIN, "Optimal Levels of Fertilization Under Risk: The Potential for Corn and Wheat Fertilization Under Alternative Price Policies in Argentina," *Am. J. Agr. Econ.* 54:1–10, Feb. 1972.

[4] GATES, JOHN M., "On Defining Uneconomic Regions of the Production Function: Comment," *Am. J. Agr. Econ.* 52:156–158, Feb. 1970.

[5] GOLDBERGER, ARTHUR S., "The Interpretation and Estimation of Cobb-Douglas Functions," *Econometrica* 36:464–472, July 1968.

[6] HALTER, A. N., H. O. CARTER, AND J. G. HOCKING, "A Note on the Transcendental Production Function," *J. Farm Econ.* 39:966–974, Nov. 1957.

[7] HOCH, IRVING, "Simultaneous Equation Bias in the Context of the Cobb-Douglas Production Function," *Econometrica* 26:566–578, Oct. 1958.

[8] HODGES, DOROTHY J., "A Note on Estimation of Cobb-Douglas and CES Production Function Models," *Econometrica* 37:721–725, Oct. 1969.

[9] KMENTA, J., "On Estimation of the CES Production Function," *Internat. Econ. Rev.* 8:180–189, June 1967.

[10] ULVELING, EDWIN F., AND LEHMAN B. FLETCHER, "A Cobb-Douglas Production Function with Variable Returns to Scale," *Am. J. Agr. Econ.* 52:322–326, May 1970.

[11] ZELLNER, A., J. KMENTA, AND J. DRÈZE, "Specification and Estimation of Cobb-Douglas Production Function Models," *Econometrica* 34:784–795, Oct. 1966.

An Econometric Analysis of the Demand for Textile Fibers*

KENNETH A. LEWIS

Dynamic demand equations for seven textile fibers were estimated (1920–1966) and simulated (1967–1970). Fiber demand has been price inelastic, helping to explain observed instability in fiber prices, where competitively, determined and the interest in price-support schemes. Significant (and dominant in cotton's case) substitution relationships existed between synthetic and other fibers.

IN THIS paper dynamic demand equations were specified and estimated for seven textile fibers using annual data from 1920 to the present. The supply function in each market was assumed to be perfectly elastic. The estimated model presents evidence of substitutability between fibers and suggests insights into the historical instability of textile-fiber prices and the nature and extent of the textile cycle.

The Demand Functions

The natural fibers (cotton, apparel wool, and carpet wool) and the man-made fibers (rayon-acetate staple and filament yarn and synthetic staple and filament yarn) were examined. The steady-state demand level (DC_{jt}^*) was specified as a function of a series of fiber prices (P_{jt}) and the level (Y_t) and (for cotton) the rate of change (ΔY_t) of real per capita income.

$$DC_{jt}^* = DC_{jt}^*(Y_t, \Delta Y_t, P_{1t}, \cdots, P_{jt}, \cdots, P_{7t}, U_{1jt}) \quad (1)$$
$$\text{for } t = 1, \cdots, T \text{ (periods)}$$
$$j = 1, \cdots, 7 \text{ (fibers)},$$

where U_{1jt} is a stochastic disturbance.

A stock-adjustment mechanism was introduced to describe the actual time pattern of demand (DC_{jt}) which produced

$$DC_{jt} = (1 - \delta_j) DC_{jt-1} + \delta_j \{ DC_{jt}^*(Y_t, \Delta Y_t, P_{1t}, \cdots, P_{7t}, U_{1jt}) \} + U_{2jt}, \quad (2)$$

where δ_j is the coefficient of adjustment.[1] The demand equations were estimated at the mill level using as the dependent variable (DC_{jt}) the poundage of each fiber processed annually.[2,3]

Prior to estimation, the cross-prices were lagged one period under the assumption that the response to other fiber-prices involved an information delay and required the investigation of new fiber sources. Throughout the period, more mills began to handle several fibers, weakening the argument, but lagged cross-prices still provided more acceptable results. Second, the synthetic price was inverted where it appeared as an other-price and the price was approximated as having been infinite in the prewar (prior to the fiber's commercial

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KENNETH A. LEWIS *is assistant professor of economics at Boston College.*

[1] The assumed dynamic adjustment mechanism is $DC_t = \delta(DC_t^* - DC_{t-1}) + U_{2t}$ [11]. An alternative specification of the stock-adjustment mechanism is $dDC_t/dt = \delta^{H-T}(DC_t^* - DC_t) + U_{2t}$. Houthakker and Taylor [7] introduced an approximation procedure to estimate the second specification. The estimated long-run elasticities and the implied reaction paths for the alternative dynamic specifications were nearly identical for three of the four fibers for which both specifications were estimated (the exception was carpet wool). Thus, the second specification was largely redundant and only its estimates for carpet wool were reported. The reaction path described by the two specifications are identical when $\ln(1-\delta) = -\delta^{H-T}$; for cotton, apparel wool, and rayon staple, this relationship held closely for the estimated δ's.

[2] For cotton and wool net imports were added to mill usage (consumption) to measure the fiber consumed domestically. Detailed foreign trade data were not available for man-made fibers and experiments with various proxies affected the results very little.

[3] Data were not available to measure the poundage of fiber demanded by final consumers, so we were forced to measure demand at the mill level. According to the theory of derived demand, the prices of finished textile products, rather than the income variables, should have been included in the equation. But again, reliable price data for finished products were unavailable. The income variables probably better proxied the impact of changes in demand for finished textile products, for competitive forces were often met by changing the quality and/or quantity of fabric in a particular end use item rather than the price of the item. An alternative interpretation of Equation (1) is as a reduced-form equation to a system similar to that of Wallace, Naylor, and Sasser [15].

production).[4] Third, two dummy shift variables were added for Depression (DD_t) and war (WD_t) years.

In the course of estimation all but one cross-price coefficient in each equation were eliminated; in no case were additional cross-price coefficients significantly different from zero (or did their exclusion appreciably affect the remaining coefficient estimates). Finally, equation (1) was specified as linear for cotton, wool, and rayon. But for synthetics, perhaps because of their rapid postwar growth, a log-linear specification was superior.

The Supply Functions

Annual textile-fiber prices were assumed to be exogenous to the mills. The annual price of cotton was historically very close to the federal support-price, which was not sensitive to current consumption.[5] The average annual price of apparel wool sold in the United States followed very closely the wool prices determined in the large international auctions [5, 18].[6] List prices for man-made fiber were administered by oligopolistic producers and were changed infrequently. Dependence upon current consumption was irregular, indirect, and not easily quantifiable.[7]

Because of the assumption that fiber prices were exogenous, the demand functions were identified and the single-equation ordinary least squares (OLS) and generalized least squares (GLS) estimates were consistent.

The Estimated Demand Equations

Estimated demand equations are presented in Table 1 and the estimated long-run coefficients and elasticities in Table 2. Each equation was estimated through 1966 (the period of estimation for each equation is listed in Table 1) and then simulated from 1967 to 1970.[8]

Autocorrelation

If in the presence of a lagged dependent variable the disturbances follow a first-order Markoff scheme, "not even the weakest condition of consistency is achieved" [16]. While positive first-order autocorrelation is frequently encountered in annual economic models, there was concern about negative serial correlation due to possible specification error. Specifically, it has been argued [10, 13, 14] that special buying patterns of intermediaries (converters) between the mill and the final consumer may have imparted a two- to three-year cycle in fiber demand at the mill level, causing annual demand to rise above and then fall below the level ultimately demanded for final consumer products. To the extent that the independent variables in Equation (1) represented only final demand, short cycles may have been left in the residuals. The Durbin-Watson (DW) statistics for OLS were typically greater than two, but using Durbin's [4] two-sided test for first-order serial correlation in the presence of a lagged dependent variable, the DW statistics were significantly greater than 2.0 only for rayon filament and possibly synthetic staple.[9] These equations were reestimated using both the three-pass generalized least squares (3PGLS) procedure of Wallis [16] and an instrumental variable estimator (IV) suggested by Griliches [6] (obtained upon the second pass of the Wallis procedure); both procedures produced almost identical results. The rayon filament equation was improved but there remained doubt about the synthetic staple estimates.

Coefficient Estimates

Own-price coefficients

Negative and inelastic own-price elasticities were expected—because textile fibers are industrial raw materials whose cost represented

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[4] This approximation is analogous to the *assumption* that the quantity consumed was zero. In effect, the synthetic fiber is assumed to have existed but at a price so high that it was rendered useless.

[5] The price paid by the mills differed from the market (support) price by the amount of an equalization rebate from April 1963 to August 1966; since the rebate was not adjusted to current consumption conditions, the assumption of exogenous prices was unaffected.

[6] Carpet wool prices may have been affected by the proportionately large United States consumption, introducing simultaneous equation bias into the estimates. No carpet wool equation was satisfactory.

[7] The man-made fiber price data are list prices which may have only proxied the effective price. As suggested by Markham [9], the rayon price data for the middle Thirties may be inaccurate, but a Chow test indicated no structural change in the rayon price coefficients. There was perhaps some discount activity in rayon in the mid-Fifties, but we were not able to adjust the list prices to incorporate such discounts.

[8] Data sources and the man-made fiber price indices are available upon request from the author.

[9] The test statistic is $K_1 = n(1-1/2d)^2/1-nV(b_1)$, where n is the number of observations, d is the Durbin-Watson statistic, and $V(b_1)$ is the estimated variance of the coefficient of the lagged dependent variable. The statistic is χ^2 with one degree of freedom, asymptotically. Since the small sample-properties of the test are not known, we remained cautious of the synthetic staple equation.

Table 1. Estimated fiber demand functions[a]

	Dependent[b] variable	Intercept	Lagged dependent variable	Y_t	own price P_{1t}	cross price $1/P_{2t-1}$	ΔY_t	WD_t	DD_t	$\bar{R}^2$	DW	F
Cotton (1922–1966)												
OLS	DC_t	17.858	.213	.572	−1.045	-9.785^1	1.146	5.304	−4.322	.92	2.29	59.7
		(10.0)	(2.6)	(3.8)	(3.5)	(5.9)	(3.4)	(6.9)	(5.4)		$\chi_1^2=1.31$	(7,37)
Apparel Wool (1925–1966)												
OLS_1	DC_t	2.464	.349		− .135	$-.707^2$		1.076	− .801	.91	2.26	71.6
		(8.8)	(4.7)		(3.0)	(5.4)		(8.9)	(6.2)		$\chi_1^2=.802$	(5,36)
OLS_2	DC_t	2.273	.285	.032	− .143	-1.029^2		1.033	− .744	.91	2.20	59.1
		(7.2)	(3.2)	(1.28)	(3.2)	(3.6)		(8.3)	(5.5)		$\chi_1^2=.630$	(6,35)
Rayon-Acetate Staple (1938–1966)												
OLS_1	MC_t		.364	$.138^e$	−1.609	$.174^1$					1.92	
			(2.1)	(3.2)	(2.1)	(.54)					$\chi_1^2=.360$	
OLS_2	MC_t		.323	$.153^e$	−2.094	$.1554^{2f}$					1.93	
			(1.6)	(3.6)	(2.5)	(.50)						
OLS_3	MC_t		.373	.147	−1.837						1.95	
			(2.2)	(3.2)	(2.9)						$\chi_1^2=.109$	
Rayon-Acetate Filament Yarn (1933–1966)												
OLS	MC_t	1.139	.668	.073	− .718	$-.833^4$		c	c	.88	2.70	
		(.6)	(6.0)	(1.1)	(.81)	(2.6)					$\chi_1^2=7.202$	
3PGLS rho = −.4	MC_t	1.016	.748	.0529	− .622	$-.715^4$		c	c	.96	2.09	
		(.7)	(8.6)	(1.1)	(.9)	(3.3)					$\chi_1^2=.093$	
Synthetic Staples[g] (1949–1966)												
OLS	LMC_t	9.236	.535	3.344	− .483	$.187^{2f}$				.993	2.62	
		(2.7)	(6.9)	(2.9)	(1.0)	(1.5)					$\chi_1^2=1.940$	
3PGLS rho = .269	LMC_t	−12.210	.48	4.367	− .277	$+.275^2$				.987	2.57	
		(3.1)	(4.9)	(3.2)	(.51)	(1.9)					$\chi_1^2=1.767$	
Synthetic Filament Yarn[g] (1947–1966)												
OLS	LMC_t	−2.746	.802	1.023	− .0246					.995	2.12	
		(1.6)	(12.5)	(1.66)	(.16)						$\chi_1^2=.079$	
OLS[d]	LMC_t	−4.17	.73	1.53						.99	2.17	

The superscripts in the other price column identify the particular fiber price included in the equation:
[1] Synthetic staple price index
[2] Acrilan staple price
[3] Carpet wool price
[4] Nylon filament yarn price index (70d.)
[a] "t values" are included in parentheses below the estimated coefficients.
[b] For the man-made fibers, the poundage of fiber purchased and shipped to the mills; for the natural fibers, the poundage of fiber processed by the mill (changes in mill fiber stocks are not appreciable). For the latter, we net out fiber manufactured into export products and add fiber imported for domestic consumption.
[c] Dummy variables not included since a Chow test indicates no significant structural change in the equation during the period (at the 5 percent level).
[d] The first observation is deleted.
[e] The independent variable is real, per capita, aggregate, personal consumption expenditures.
[f] The other price variable is not inverted.
[g] The variables are the natural logarithms of the original variables.

a small proportion of the cost of textile end-products and because textile end-products were considered more as "necessities" than "luxuries." Cotton, which was used primarily to produce cheap staple items rather than more luxurious items, was expected to have the lowest elasticity. The own-price elasticities were inelastic (although not all were significantly different from zero) and lowest for cotton. For three of the four man-made fibers, the own-price coefficients were insignificant, but because of collinearity, the income variable may have picked up some of the own-price effects.

Tests were performed for the possibility that the cotton, wool, and rayon equations underwent structural change during the early Fifties with the large-scale introduction of synthetic fiber.[10] There was concern that the own-price coefficients may have become more elastic with the rapid introduction of a substitute good. Evidence of structural change (testing across all coefficients) was found only in the carpet wool equation (occurring in the middle Sixties), but data were not available to test

[10] Two alternative test procedures were adopted: (1) the Depression and war years were excluded from the sample and the usual Chow [3] test was conducted; (2) the Chow test originally designed for situations where the number of observations in the second period is less than the number of variables was used; the latter test is less powerful than the usual Chow procedure.

Table 2. Estimated steady-state coefficients and elasticities

	Equation	δ	δ^{H-T}	Income[a] elasticity of demand	Own-price[a] elasticity of demand	Other price[b] elasticity of demand	Gross substitute (S) or complement (C)	Coefficient of WD as percent of 1940 consumption	Coefficient of DD as percent of 1930 consumption
Cotton	OLS	.79		.37	− .17	$+.48^{1}$	S	+18% (+)	−16% (−)
	H-T-OLS[e]		1.69	.37	− .17	$+.47^{1}$	S		
Apparel wool	N-OLS$_1$	.65			− .44	$+.54^{2}$	S	+42% (+)	−35% (−)
	N-OLS$_2$	.72		.27	− .44	$+.69^{2}$	S		
Carpet wool	H-T-OLS		.80	1.09	− .51	$+.18^{c}$		−48%	
Rayon-Acetate staple	N-OLS$_1$	.64		1.45	− .46	$-.065^{1}$	C	d	
	N-OLS$_2$	.68		1.52	− .56	$+.071^{3}$	S	d	
	N-OLS$_3$	.63		1.52	− .50	$-.029^{1}$	C	d	
Synthetic staple	N-3PGLS	.52		8.48	− .54	$+.53^{2}$	S		
	N-OLS	.47		7.20	−1.04	$+.40^{3}$	S		
	N-C-O	.51		6.22	−1.61	$+.22^{3}$	S		
Rayon-Acetate filament yarn	N-OLS	.33		.96	− .56	$+.68^{4}$	S	d	
	N-3PGLS	.25		.92	− .64	$+.77^{4}$	S	d	
Synthetic filament yarn	N-OLS	.20		5.09	− .12				
	N-3PGLS	.19		4.73	− .29				
	N-OLS	.27		5.70					

The superscripts in the "other price elasticity" column identity the fiber—see code in Table 1.
[a] The point elasticity is calculated at the mean values of the variables.
[b] For indices 1, 2, and 4, the point elasticity is calculated at the 1966 values of the variables. (The partial derivatives of consumption with respect to the synthetic prices are a function of the price level.)
[c] The percentage response of carpet wool consumption to synthetic staple consumption, measured at mean values.
[d] War dummy variables have not been included for these equations.
[e] Included to show the similarity of the two approximation schemes discussed in footnote 3. The ln $(1-\delta)=1.56$, while $\delta^{H-T}=-1.69$, illustrating the similarity of the implied reaction paths.

whether the own-price elasticity actually increased.[11]

Cross-price coefficients

The cross-price coefficients in the cotton, wool, and rayon equations indicated an expected significant substitute relationship between these fibers and synthetic fibers. Except for the marginal significance of the carpet wool price in the synthetic-staple equation, these cross effects were not confirmed in the synthetic equations, but this may have been due to the limited number of degrees of freedom in the equations.

As seen in Table 2, changes in the prices of the different synthetic fibers (acrylic staple, nylon filament, and the staple index) had approximately the same long-run impact on the demand for cotton, apparel wool, and rayon filament, although the full impact upon cotton occurred much sooner. In the long run cotton was almost three times more responsive to changes in the synthetic-fiber price than to changes in its own price, which is not unreasonable, given the rapid introduction of synthetized products which could better satisfy some (but not all) of the end uses previously satisfied by cotton. This highlighted the great impact of synthetic fiber on cotton's market share (which dropped from 80 percent in 1935 to 42 percent in 1970).[12]

While the other-price coefficients were highly significant, one could not conclude that price differences were the primary vehicle for interfiber competition because the price variables (which trended downward) mayhaveproxied the effects of non-price aspects of fiber competition which others have stressed [1, 17, 19]. Such non-price factors include quality improvement, successful promotional campaigns, stable supplies, and technical assistance in handling synthetic fibers. While it was difficult to distinguish between price and non-price factors, the marginal significance of the carpet wool price in the synthetic staple equation was suggestive of relative price sensitivity.

It was surprising that when different rayon-acetate prices, including tire cord yarn, were included in the cotton equation (both with and without a synthetic fiber price), none achieved even marginal significance. Markham [9] has anticipated this result for the prewar period by arguing that rayon competed more with silk than with cotton or wool. However, there have been historical examples of rayon replacing

[11] Thus, the hypothesis that the wool, cotton, and rayon income elasticities dropped as synthetic fibers took over some of the "glamour" end uses was also rejected.

[12] Figures do not include textile glass fiber.

cotton in selected end uses (e.g., tire cord yarn). The hypothesis of *price* competition between cotton and rayon was rejected. Technological non-price aspects were believed to be responsible for direct competition which occurred.

Income elasticities

As expected, the estimated income elasticities, reflecting the growth potential of various fibers, were inelastic for cotton and wool and elastic for the man-made fibers which have pioneered many new end uses. The man-made fiber income elasticities were larger than expected perhaps because, as suggested above, they picked up both price and income effects or because they proxied in part the impact of non-price aspects of fiber competition. As such, the coefficients were not strictly comparable to those for natural fibers. Data were insufficient to isolate the relative importance of changes in disposable income, in own-prices, and in technological, non-price factors for man-made fibers.[13]

Reaction speeds

The estimated reaction speeds were similar for fibers with similar attributes and end uses and fastest for apparel wool and cotton, slower for carpet wool and man-made staple, and slowest for man-made filaments. On the hypothesis that reaction speed was slower for 1) more durable and 2) newly-introduced products, such a pattern is reasonable: the filament yarns serviced highly durable industrial end uses; the staples and carpet wool provided semi-durable household items; and the long-established cotton and apparel wool fibers served less durable end uses.

Forecasts of Mill Consumption

The model was simulated beyond the period of estimation from 1967–1970.[14] As seen in Table 3, the model predicted fairly well consumption levels in the very near future (and in a few cases as far ahead as three years), but the quality of the forecasts generally deteriorated thereafter.[15] To be useful in helping to establish import quotas or price support levels, the forecasts need to be updated continually and the model retested for possible structural change. The synthetic staple and carpet wool equations performed particularly poorly here, reinforcing earlier reservations about their specification.

Table 3. Simulated and actual fiber demand (1967–1970) pounds per capita

		1967	1968	1969	1970
Cotton (OLS)	$\hat{DC}$	24.354	23.040	20.579	20.175
	$\overset{*}{DC}$	23.496	22.029	20.613	19.900
Actual percent error		+3.65%	+4.59%	−.16%	+1.38%
Apparel wool (OLS_1)	$\hat{DC}$	1.910	1.964	1.972	1.986
	$\overset{*}{DC}$	1.680	1.826	1.630	1.295
Percent error		+13.69%	+7.56%	+20.98%	+53.36%
R-A Staple (OLS_2)	$\hat{MC}$	4.096	4.193	4.295	4.324
	$\overset{*}{MC}$	3.820	4.440	4.288	3.476
Percent error		7.23%	5.58%	.16%	24.40%
R-A Filament (3PGLS)	$\hat{MC}$	3.883	3.834	3.785	3.723
	$\overset{*}{MC}$	3.715	3.950	3.659	3.406
Percent error		+4.52%	2.94%	3.44%	9.31%
Synthetic Staple (3PGLS)	$\hat{MC}$	5.936	7.683	9.235	10.107
	$\overset{*}{MC}$	5.689	7.568	8.310	8.474
Percent error		4.34%	1.52%	11.13%	19.27%
Synthetic Filament (OLS)	$\hat{MC}$	6.470	7.576	8.688	9.835
	$\overset{*}{MC}$	5.950	7.732	8.115	8.782
Percent error		8.74%	2.02%	7.06%	11.99%

* Represents actual demand.

Summary and Implications of the Estimated Models

Where significant, the own-price elasticities were inelastic, which was expected for agricultural products and industrial raw materials. To the extent that the farmers' supply functions for wool and cotton were also price inelastic, a small shift in the demand or supply curves of either fiber could have led to a large change in its price if it were not supported. Historically, such instability in natural fiber prices has occurred where prices were competitively determined [2, 18]. This explains in part the

[13] The insignificance of the apparel wool income coefficient may have been due to multicollinearity or the offsetting influence of increased aggregate purchasing power and increased interior and automobile heating and a style trend toward lightweight clothing.

[14] The simulation used the actual values of the exogenous variables and the simulated value of the lagged dependent variable, thus compounding forecast error.

[15] In an earlier version of this paper, market shares were forecast which were accurate for only two or three years beyond the sample; the forecasts are available upon request.

great interest in price-support and minimum-price schemes to protect cotton and wool growers in the United States and other free-world producing countries [18].[16]

Because of the inelastic demand, a relatively large change in the price-support level is necessary to effect a relatively small change in the level of mill consumption. Thus, if fibers begin to stockpile, a large price increase may be required to reverse the trend, which complicates the selection of a proper support level if stabilization funds and storage space are limited for long time periods. The success of stabilization schemes then is even more dependent upon the prediction of future demands and supplies of the fiber, which, if the forecasting success above is indicative, is no easy task and one that requires continual updating of the model.

The significant cross-relationships between the synthetic fibers and cotton, wool, and rayon indicate that policy decisions affecting the price of one fiber may have some impact on the other markets in the industry. Government pricing and stockpile policy for natural fibers (and especially cotton) may affect or even be offset by or confounded by changes in the man-made fiber sector.

[16] Additional empirical knowledge of the producer supply functions and export demand functions would enable the evaluation of different price support schemes in terms of economic efficiency.

Even though the DW statistics were typically greater than two, only scattered evidence was found of significant negative autocorrelation. This implies that if a textile cycle existed (and some marginal evidence has been found [8]), it was accounted for by the structure and/or fluctuations in the independent variables (most likely Y_t) and was not left in the residual. This tentatively characterizes the textile cycle, if it exists, as reflecting short cycles elsewhere in the economy rather than arising from converters' special buying patterns unrelated to other activity.

While the equations attest to the importance of economic factors explaining fiber consumption, they leave room for the importance of other factors such as technological change, quality improvement, promotional success, and style change. In fact, it is difficult to sort out the relative importance of economic technological factors since economic variables may have proxied technological factors. In any event, it does not appear that difficult-to-quantify technological factors were important enough to invalidate quantitative economic models or that synthetic fiber growth was exogenous to the economic system, as some have previously claimed [12].

References

[1] BARLOWE, RUSSELL G., AND JAMES R. DONALD, "U. S. Demand for Cotton: Trends and Prospects," *Cotton Situation*, Washington, USDA, March 1971.

[2] BURLEY, S. PETER, "Fluctuations in the Australian Economy: Viewed by Frequency Techniques," Princeton University, Econometric Research Program, Research Memorandum 94, March 1968.

[3] CHOW, GREGORY C., "Tests of Equality Between Sets of Coefficients in Two Linear Regressions," *Econometrica* 28:591–605, July 1960.

[4] DURBIN, J., "Testing for Serial Correlation in Least-Squares Regression When Some of the Regressors Are Lagged Dependent Variables," *Econometrica* 38:410–421, May 1970.

[5] FERGUSON, C. E., AND METODEY POLASEK, "The Elasticity of Import Demand for Raw Apparel Wool in the United States," *Econometrica* 30:670–699, Oct. 1962.

[6] GRILICHES, ZVI, "Distributed Lags: A Survey," *Econometrica* 35:16–49, Jan. 1967.

[7] HOUTHAKKER, H. S., AND LESTER D. TAYLOR, *Consumer Demand in the United States, 1929–1970, Analyses and Projections*, Cambridge, Harvard University Press, 1966.

[8] LEWIS, K. A., "Textile Mill Fiber Consumption in the United States: An Econometric Analysis," Princeton University, Econometric Research Program, Research Memorandum 109, March 1969.

[9] MARKHAM, JESSE W., *Competition in the Rayon Industry*, Cambridge, Harvard University Press, 1952.

[10] MIERNYK, W. H., AND MANUEL ZYMELMAN, *Inventories in the Textile Cycle*, Washington, U. S. Dept. of Commerce, 1961.

[11] NERLOVE, MARC, *Distributed Lags and Demand Analysis for Agriculture and Other Commodities*, USDA Agr. Handbook 141, 1958.

[12] POLASEK, METODEY, AND ALAN POWELL, "Wool Versus Synthetics: An International Review of Innovation in the Fiber Market," *Australian Econ. Papers* 3:49–64, June–Dec. 1964.

[13] SCHAFFIR, KURT H., "Operations Research in the Textile Industry," in *Publications in Operations Research*, New York, John Wiley & Sons, Inc., 1964.

[14] STANBACK, T. N., JR., "The Textile Cycle: Characteristics and Contributing Factors," *South. Econ. J.* 25:174–188, Oct. 1958.

[15] WALLACE, WILLIAM H., THOMAS H. NAYLOR, AND W. EARL SASSER, "An Econometric Model of the Textile Industry in the United States," *Rev. Econ. & Stat.* 50:13–22, Feb. 1968.

[16] WALLIS, KENNETH F., "Lagged Dependent Variables and Serially Correlated Errors: A Reappraisal of Three-Pass Least Squares," *Rev. Econ. & Stat.* 49:555–567, Nov. 1967.

[17] WARD, LIONEL E., "Interfiber Competition with Emphasis on Cotton," unpublished Ph.D. thesis, University of California, Davis, 1968.

[18] WITHERELL, WILLIAM H., "Dynamics of the International Wool Market: An Econometric Analysis," Princeton University, Econometric Research Program, Research Memorandum 91, Sept. 1967.

[19] YALE, JORDAN P., "The Strategy of Nylon's Growth: Create New Markets," in *Modern Textiles Magazine*, New York, Rayon Publishing Corp., Jan. 1964.

Demand, Supply, and Price Relationships for the Broiler Sector, With Emphasis on the Jack-Knife Method

Russell G. Thompson, J. Michael Sprott, and Richard W. Callen

Parameters of a simultaneous equation model of the broiler sector were estimated by 2SLS, OLS, and JK procedures as proposed by Tukey and Hartley and Hartley. Results indicate that 2SLS and OLS methods may significantly underestimate the standard errors of the coefficients.

In this study estimates of a simultaneous equation model for the broiler sector[1] which allowed for simultaneity between quantity and price were computed by ordinary least squares (OLS), two-stage least squares (2SLS), and jack-knife (JK) procedures, as proposed by Tukey [9] and modified by Hartley and Hartley [4]. Four relationships are included in the model. One is the demand-supply identity; the other three are (1) the supply of broilers, (2) the demand for broilers, and (3) the margin between the retail and farm prices of broilers.

Use of the JK method is emphasized in this study. Its primary objective is to overcome the bias of estimating the standard errors of the coefficients by asymptotic procedures such as 2SLS. The power of this technique could be important in an evaluation of the simultaneity between demand and supply because the bias is commonly in the form of underestimation.

Since the Hartley-Hartley extension of the JK procedure is relatively new, it may be helpful to indicate here how the sequences of time-series observations are analyzed. Suppose for purposes of illustration that five annual time-series observations are being analyzed and that quantity is being regressed on price. That is, $q=\alpha+\beta p$ is the expected value form of the regression model. Further, suppose the length of time-series sections to be analyzed is 3—the value of k.

Denoting the set of observations as follows:

$$\{(p_1, q_1), (p_2, q_2), (p_3, q_3), (p_4, q_4), (p_5, q_5)\},$$

then the sets of observations for the five sectional estimates are[2]

$$S_1 = \{(p_1, q_1), (p_2, q_2), (p_3, q_3)\},$$
$$S_2 = \{(p_2, q_2), (p_3, q_3), (p_4, q_4)\},$$
$$S_3 = \{(p_3, q_3), (p_4, q_4), (p_5, q_5)\},$$
$$S_4 = \{(p_4, q_4), (p_5, q_5), (p_1, q_1)\},$$
$$S_5 = \{(p_5, q_5), (p_1, q_1), (p_2, q_2)\}.$$

Using regression techniques, $\hat{\alpha}_i$, $\hat{\beta}_i$ are calculated for the data sets,

$$S_i,\ i = 1, 2, \cdots, 5.$$

The JK estimates are[3]

$$\tilde{\alpha} = 1/5 \sum_{i=1}^{5} \hat{\alpha}_i \quad \text{and} \quad \tilde{\beta} = 1/5 \sum_{i=1}^{5} \hat{\beta}_i.$$

The Model

Definitions

To state the model, the following definitions are used: $y_1(t)$ is the quantity of broilers in

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[1] In nine out of 11 econometric analyses of the broiler sector, prime emphasis was given to the demand side of the models estimated. Supplies were assumed to be predetermined by all except Cromarty [1] and Fisher [2]. Cromarty was concerned with the total agricultural economy and represented the broiler sector by two equations in a 14-equation model. Fisher sought to evaluate the degree of simultaneity between supplies and demands for poultry products and to make a quantitative study of the poultry industry for the years 1915 through 1940, prior to the development of the specialized broiler industry in the United States.

In 1953 Fox [3, p. 50], who found a lack of simultaneity between annual demands and supplies for most important agricultural commodities, indicated that this was not likely to be true for the broiler sector. In 1965 Tomek [8, p. 797] was still concerned about this possible simultaneity for the annual time series; yet this hypothesis has not been formally evaluated by the use of simultaneous equation methods for most of the post-World War II period, in which the specialized broiler industry has developed. This evaluation may be made from the analysis below.

Russell G. Thompson *is a professor in the Department of Quantitative Management Science at the University of Houston;* J. Michael Sprott *is an extension specialist in the Department of Agricultural Economics, Texas A&M University; and* Richard W. Callen *is a lecturer in the Department of Quantitative Management Science, University of Houston.*

[2] See Appendix for formulas to calculate the variances of $\tilde{\alpha}$ and $\tilde{\beta}$.

[3] Note that sets S_i, $i=1, 2, \cdots, 5$ are not mutually exclusive.

pounds per capita supplied in year t [13]; $y_2(t)$ is the average annual farm price of broilers in year t, in cents per pound [16], deflated by the index of prices received by farmers [14]; $y_3(t)$ is the average annual retail price of broilers in year t, in cents per pound [12], deflated by the consumer price index [18]; $y_4(t)$ is the quantity of broilers demanded in pounds per capita in year t [13]; $x_1(t)$ is the number of broilers supplied in year $t-1$, in millions of head [10]; $x_2(t)$ is the cost of feed per pound of liveweight broiler produced in year $t-1$, cents per pound [15], deflated by the index of prices paid by farmers [11]; $x_3(t)$ is the average annual index of the retail price of red meat—value weighted index of beef, veal, lamb, mutton, pork, and ground meat—in year t, in cents per pound [17], deflated by the consumer price index [18]; and $x_4(t)$ is the index of real per capita disposable income in year t, 1957–59 = 100 [19], deflated by the consumer price index [18].

Relationships in the model

Per capita supply of broilers is

(1) $y_1, y_2;\quad x_1, x_2.$

Per capita demand for broilers is

(2) $y_4, y_3;\quad x_3, x_4.$

The marketing margin is

(3) $y_3, y_2:$

The supply-demand identity is

$$.74y_1 = y_4.$$

Some special considerations

Feed cost per pound of liveweight broiler produced in year $t-1$ is based on reported prices paid by producers for broiler growing mash and chicken mash. These costs are probably higher than those that would be incurred by highly integrated operators; however, year-to-year changes are believed to be fairly representative of changes in feed prices for the broiler industry as a whole. From 1963 through 1968, feed cost is based on growing feed for broilers instead of growing mash.

The index of red meat price is used in the model as an indicator of substitute prices, rather than the prices of the individual red meats, to minimize the problems of multicollinearity. Since capacity varies with the intensity of use, it was difficult to arrive at a good indicator of broiler productive capacity. Fisher [2, p. 40] used the number of hens, pullets, and other chickens per capita on January 1. Cromarty [1, p. 565] used an index of physical units of poultry equipment on farms. It was also necessary to use a proxy variable here as a capacity indicator—the number of broilers producer in year $t-1$.

Data base and value of k

To estimate the model, 34 annual time-series observations (1935–68) were analyzed, including the war years. This represented the data base available for all of the variables at the time of this study.

In this study the parameter k in the Hartley modification of the JK method is taken to be 15. Fifteen years closely approximates the economic life of broiler facilities, as well as the period of intense production expansion beginning in the early Fifties and continuing to the present. Moreover, preliminary tests with $k = 14$ and $k = 13$ indicated substantial increases in the variances of the coefficients as k decreased. To date, no specific rule for selecting k has been developed.

Estimates of the Supply and Demand Relationships

Estimates of the coefficients for the supply and demand relationships are presented in Tables 1 and 2.[4]

Supply estimates

Strong negative relationships of similar magnitudes and significance were found in the 2SLS and OLS estimates of the relationships between the per capita supply of broilers and the farm price, as well as between this supply variable and the cost of feed in the previous year. Also, a strong positive relationship similar in magnitude and significance was found in the 2SLS and OLS estimates of the relationship between the per capita supply of broilers and the capacity indicator—the number of broilers produced in the previous year. However, the JK estimate indicated the farm price and the feed cost were both insignificant. Only the capacity variable was found to have a significant effect on the quantity of broilers supplied.[5] Thus, the

[4] See Appendix Table for estimates of margin relationship.

[5] This finding seems to be in agreement with the results found by Cromarty [1] and Fisher [2]. Only capacity and time were found to be significant by Fisher [2, p. 47].

Table 1. Estimates of coefficients in the supply relationship*

Estimation method	Coefficients				R^2	d
	Constant	Farm price (y_2)	Feed cost (x_2)	Capacity (x_1)		
2SLS	9.72	−.09	−.21	.01	—	—
	(1.68)	(−.036)	(−.075)	(.00046)		
OLS	9.80	−.10	−.20	.01	.996	2.13
	(1.66)	(−.033)	(−.071)	(.00045)		(NS)
JK(2SLS)	11.34	−.16	−.17	.01	—	—
	(2.7)	(−.225)	(−.436)	(.00068)		

* The respective estimated standard errors are given in parentheses below the estimated coefficients; d is the estimated value of the Durbin-Watson statistic, with NS indicating insignificance at the 5-percent level for a two-tailed test. Table $d_L = 1.17$, $d_u = 1.55$. However, the value of Durbin-Watson statistics is presently being reconsidered (*cf.*, Kadiyala [5]).

Table 2. Estimates of coefficients in the demand relationship*

Estimation method	Coefficients				R^2	d
	Constant	Retail price (y_1)	Meat price (x_3)	Income (x_4)		
2SLS	6.97	−.39	.18	.01	—	—
	(2.32)	(.022)	(.027)	(.001)		
OLS	4.41	−.37	.18	.01	.98	1.12
	(2.20)	(.021)	(.027)	(.00088)		(S)
JK(2SLS)	−4.91	−.34	.22	.01	—	—
	(−9.82)	(−.077)	(.05)	(.0045)		

* The respective estimated standard errors are given in parentheses below the estimated coefficients; d is the estimated value of the Durbin-Watson statistic, with S indicating significant serial correlation at the 5-percent level for a two-tailed test, $d_L = 1.17$, $d_u = 1.55$.

effects of farm price and feed costs must be largely subsumed in the factors determining investments in capacity.

The differences between the standard errors of the 2SLS and JK estimates indicate the possible underestimation bias of the 2SLS procedure. In the case of the farm price variable, for example, the JK estimate of the standard error is more than six times larger than the 2SLS estimate (in absolute value).

Demand estimates

Strong negative relationships of similar magnitudes were found in the 2SLS, OLS, and JK estimates of the relationship between the per capita demand for broilers and the retail price of broilers. Strong positive relationships of similar magnitudes were found in the relationship between per capita demand and the index of red meat prices, and between demand and the index of real disposable income per capita. Again, as found for the supply estimates, the estimated standard errors of the coefficients were considerably greater for the JK estimate than for the 2SLS and OLS estimates. For example, the estimated standard errors for the retail price and income coefficients were at least three times smaller for the 2SLS than for the JK estimate.[6]

In summary, the standard errors of the coefficients estimated by 2SLS and OLS methods were found to be significantly smaller than those estimated by the JK method. Ghis resulted in different conclusions to the tests of significance for the supply estimates. Thus, the traditional methods of estimation may be resulting in misleading economic inferences.

[6] For both the demand and the supply relationships, the sectional estimates tended to vary systematically with time as the producers adopted new methods of production and the consumers adjusted to a better quality, lower priced product. Thus, there may be an important dynamic element in the time series data, as stressed by Tintner [7] and Moore [6]. See Tomek's analysis [8] for further indication of this possibility.

References

[1] CROMARTY, WILLIAM A., "An Econometric Model for United States Agriculture," *J. Am. Stat. Assoc.* 54:556–574, Sept. 1959.

[2] FISHER, MALCOLM R., "A Sector Model—The Poultry Industry of the U.S.A.," *Econometrica* 26:37–66, Jan. 1958.

[3] FOX, KARL A., *The Analysis of Demand for Farm Products*, USDA Tech. Bull. 1081, Sept. 1953.

[4] HARTLEY, H. O., AND M. J. HARTLEY, "Jack-Knife Variance Estimation for Simultaneous Equations," presented at the 1968 Winter Meeting, Econometrica Society, Evanston, Ill.

[5] KADIYALA, KOTESWARA RAO, "Testing for the Independence of Regression Disturbances," *Econometrica* 38:97–117, Jan. 1970.

[6] MOORE, HENRY LUDWELL, *Synthetic Economics*, New York, The Macmillan Company, 1929.

[7] TINTNER, GERHARD, "The Theory and Measurement of Demand," *J. Farm Econ.* 21:606–613, Aug. 1939.

[8] TOMEK, WILLIAM G., "Changes in Price Elasticities of Demand for Beef, Pork, and Broilers," *J. Farm Econ.* 47:793–802, Aug. 1965.

[9] TUKEY, JOHN W., "Bias and Confidence in Not-Quite Large Samples," (Abstract), *Ann. Math. Stat.* 29:614, June 1958.

[10] U.S. Department of Agriculture, *Agricultural Statistics, 1950*, Table 571; *1960*, Table 606; *1960*, Table 593.

[11] ———, *Handbook of Agricultural Charts, 1966; 1968*, Agr. Handbook 325, Oct. 1966; Agr. Handbook 359, Nov. 1968.

[12] ———, ERS, *Poultry and Egg Situation*, PES-161, Table 12, 1935–39; PES-192, Table 20, 1940–49; PES-254, Table 4, 1950–55; PES-259, Table 3, 1956–68.

[13] ———, ERS, *Poultry and Egg Situation*, PES-211,

Table 26, 1935–54; PES-219, Table 3, 1955–59; PES-357, Table 16, 1960–68.
[14] ———, ERS, *Poultry and Egg Situation*, PES-234, Table 10, 1935–62; *Agricultural Statistics, 1969*, Table 619, 1963–68.
[15] ———, ERS, *Poultry and Egg Situation*, PES-234, Table 10, Col. 4, 1935–50; PES-234, Table 2, 1948–57; PES-255, Table 2, 1958–68.
[16] ———, ERS, *Poultry and Egg Situation*, PES-234, Table 10, 1935–62; PES-257, Table 2, 1963–68.
[17] ———, ERS, *U.S. Food Consumption*, USDA Stat. Bull. 364, Table 95, 1935–55; *National Food Situation*, No. 125, Table 11, 1956–68.
[18] ———, ERS, *U.S. Food Consumption*, USDA Stat. Bull. 364, Table 98, 1935–55; *Poultry and Egg Situation*, PES-359, Table 3, 1956–68.
[29] ———, ERS, *U.S. Food Consumption*, USDA Stat. Bull. 364, Table 95, 1935–54; *Poultry and Egg Situation*, PES-259, Table 3, 1955–68.

Appendix

Formulas for jack-knife estimates

Let $\hat{\theta}_j$ represent a "sectional estimate" of a structural parameter, where $t=j, j+1, \cdots, j+k+1$, $k \leq 1/2(T-l)$, l is the maximum lag, and T is the number of observations. Then the JK estimates as developed by Hartley and Hartley [4] are

$$\bar{\theta} = \left(\frac{1}{T}\right) \sum_{j=1}^{T} \hat{\theta}_j,$$

$$\mathrm{Var}(\bar{\theta}) = (1/T^2)\left(T\hat{L} - \sum_{d=1}^{T-1} s_d^2\right)$$

where

$$\hat{L} = \sum_{d=1}^{D} s_d^2 x_d \Big/ \sum_{d=1}^{T-1} x_d^2,$$

$$s_d^2 = (1/2) \sum_{i=1}^{T} (\hat{\theta}_i - \hat{\theta}_{i+d})^2, \quad d = 1, 2, \cdots, D,$$

$$x_d = [1 - (d - D)^2/D^2], \quad d = 1, 2, \cdots, D,$$

and

$$D = \begin{cases} T/2 \text{ if } T \text{ is even} \\ (T-1)/2 \text{ if } T \text{ is odd.} \end{cases}$$

Appendix Table. Estimates of the marketing margin coefficients

Method	Item	Constant	Farm price (y_1)
OLS	Coefficient	30.65	.90
	t-value	(7.4)	(6.4)
2SLS	Coefficient	30.67	.90
	t-value	(7.4)	(6.2)
JK(2SLS)	Coefficient	31.73	1.04
	t-value	(1.2)	(1.1)

Risk Programming: An Aid in Planning Reservoir-Irrigation Systems*

J. R. CONNER, R. J. FREUND, AND M. R. GODWIN

Risk programming and simulation are used to develop a model which illustrates the effects of risk on farmers' managerial decisions and the optimal design parameters of a reservoir-irrigation system. Since variations in water availability affect enterprise choice and farm income, farmers' reactions to risk are deemed important.

RESEARCH pertaining to theories and methodologies for incorporating risk into planning models has been based on the expected utility hypothesis [6, 17] and game theory [15]. Of these, the expected utility hypothesis has been most frequently employed as the point of departure for research effort. The expected utility approach usually results in planned trade-offs between the expected level of income and the variance of income. This principle has been applied in the selection of investment portfolios [12] and to a number of agricultural planning problems [8, 9, 13, 14, 18]. The application of the principle made in this paper is designed to illustrate how risks can be incorporated into planning activities for reservoir-irrigation systems.

In this paper risk programming and simulation are used to develop a water resource system model to study the effects of variability of available irrigation water on farmer's managerial decisions. Special emphasis is given to the manner in which risk aversion affects the choice of enterprises and enterprise combinations. The effects of variability of available irrigation water on the optimum water resource system design have been discussed by the authors elsewhere [3, 4].[1]

The Reservoir-Irrigation System

The risk elements considered in this study are hydrologic in nature. That is, the study is concerned with only that risk which arises from the variations in the amount of total water available for crop production. These variations are caused by variations in stream inflow to the reservoir, evaporation from the reservoir, and rainfall in the irrigation development.

The amount of water available for crop production and its variation are manipulated by changing the levels of certain design variables of the system. These design variables are the number of acres planned for irrigation (I), the amount of water, including rainfall, planned to be furnished to each irrigated acre (T), and the capacity of the reservoir (R). The boundaries of the system are

$$60 \le R \le 300 \text{ (1,000 acre-feet)}$$
$$0 \le I \le 20 \text{ (1,000 acres)}$$
$$40 \le T \le 68 \text{ (inches of available water).}$$

It is assumed that the irrigation district for the reservoir consists of 20,000 acres divided into 60 typical farms of 333 acres each. Farmers in the irrigation district were assumed to use the water and other resources available to them in any manner they chose. For example, if the system planners provided for four feet of total available water for half of the acres in the development (10,000 acres or 166.7 acres per farm), the farmers could use that water to irrigate intensively only 100 acres per farm, leaving 233 acres without supplemental water. Thus, it was necessary to define separate crop production enterprises for various irrigation intensities including dry land operations. The enterprises and the irrigation intensities are

Cotton—*dry land* or *irrigated once, twice,* or *three* times;

Sorghum—*dry land* or *irrigated once, twice, three,* or *four* times;

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[1] Traditionally, the assumption has been made that the reliability of irrigation water delivery has no effect on decisions of farmers with respect to enterprise choice or cultivation intensity [1, 11].

J. R. CONNER *is assistant professor of food and resource economics, University of Florida.* R. J. FREUND *is professor and associate director of the Institute of Statistics, Texas A&M University.* M. R. GODWIN *was formerly professor of agricultural economics, Texas A&M University.*

Oats—*dry land* or *irrigated;* and
Alfalfa—can only be produced with *irrigation*.

Budgets of the type suitable for linear programming were developed for each of these enterprises. Functions relating yield to actual water availability were also derived for each of the 12 enterprises. These budgets and functions were used to obtain the net revenues for the farm and the total irrigation development for any enterprise combination and level of water availability.[2]

Simulation Model

A particular irrigation system was specified by the planned system design variables R, I, and T and the degree of risk aversion by the farmers. The system design variables determined the quantity and reliability of the irrigation water delivery, while the degree of risk aversion determined the farmers' reactions to variable water deliveries. The basic hydrologic data necessary for the simulation consisted of actual monthly rainfall, stream flow, and evaporation data for the 39-year period of 1916–1954 [16].

The model can be described as consisting of four basic steps as outlined below. The functional form of the model and a more detailed description of its operations can be found in [2].

1. A schedule of total annual water availabilities per farm, including both rainfall and supplemental water deliveries, was obtained by simulating the operation of a particular system through the 39-year period. Annual water availabilities included any shortages that occurred because the system was not able to provide adequate irrigation water to meet the "planned" total water levels (T).
2. The schedule of total annual water availabilities per farm was employed to obtain a schedule of annual yields for each of the 12 enterprises (4 crops with different irrigation intensities) for each year. The crop responses to water that were used in this simulation procedure were of such configuration that yields from the intensively irrigated enterprises were more adversely affected by inadequate water delivery than were the less intensively irrigated or dryland enterprises.
3. The optimum farm plans as affected by the variability of water delivery were obtained by a risk programming procedure developed by Freund [5]. This procedure is based on the premise that farmers choose an optimum mix of enterprises with full knowledge of the means and variances of net revenues of the enterprises and that this choice is made according to the expected utility hypotheses [6, 17]. Assume that a farmer prefers one enterprise mix over other alternative enterprise mixes solely on the basis of the expected net revenue and associated variance of net revenue from each enterprise mix; i.e., that he has a net revenue-variance utility function. Also assume that the farmer's iso-utility curves are convex and that there exists a normal probability distribution for the net revenues (P) from the enterprises. Given these assumptions, farmers should seek to maximize the function

$$(1) \quad E(U) = E(P) - \alpha[V(P)], \ \alpha \geq 0,$$

where E and V are the expectation and variance of money income, respectively [5, p. 255]. Alpha is a risk aversion constant and determines the degree a farmer discounts variance from income expectations in his decision-making process. In other words, farmers maximize expected revenue discounted by alpha times the variance of revenue. If $\alpha=0$, a farmer would not discount risk at all and would be concerned only with maximizing average (expected) net revenue.

Freund demonstrated that equation (1) could be adapted into a linear programming model resulting in a quadratic programming problem. Since the resulting function to be maximized is concave to the origin while the restrictions remain linear, it is possible to solve this problem by the use of an algorithm developed by Hartley and Hocking [7] and programmed by LaMotte and Oxspring [10]. The optimal (maximized) solution of the quadratic programming problem provided the acreages of each of the enterprises and the average annual net returns to each farm.
4. The remainder of the simulation model was designed to compute the primary net

[2] Details of these budgets and functions can be found in Conner [2].

benefits which were used as an indication of the economic efficiency of the system. The primary benefits were obtained by multiplying the total returns to the farm by the number of farms in the irrigation district (60) and then subtracting the net returns to the district that could be obtained if no irrigation water were available. From this remainder the discounted annual repayment costs of the reservoir and irrigation development construction capital and the annual operation and maintenance costs were subtracted. This final difference was the average annual primary net benefits that society would realize from the construction and operation of the system at a particular level of the design variables T, I, and R and at an assumed level of farmers' risk preference, α.

The system model thus described could be considered to consist of two basic sets of simulations. The first simulations are performed to obtain estimates of the means and variances of crop revenues. These estimates are the ones from which the farmers select their optimal enterprise combinations. The second and final simulations show the annual returns to the farmers based on their selected optimal enterprise mix. These actual returns are then used to compute the final net benefit evaluation for a specific combination of values of the variables T, I, R, and α. This final simulation consists of repeating the process for the various combinations of these four variables and determining the net benefits due to the system for each combination.

Basic Assumptions and Constraints

Although the model allowed for variations in the farmers' incomes due to variations in the amount of water available for crop production, it was assumed that the farmers knew the nature of the variations they faced. That is, the model allowed for only risk, not uncertainty.

The model deviates somewhat from reality because the operators of the system were assumed to deliver all of the water demanded by the crops at the time it was needed with no regard for the possibility of incurring shortages in the future. More realistic operational procedures allow for partial deliveries of water when the reservoir level becomes low to insure against the total loss of a crop later in the season due to lack of water.

Because of the limited amount of data available regarding the response of crops to water and particularly the effects of the timeliness of water availability, it was necessary to assume that the enterprises responded to total annual water regardless of when it became available within the year. The consequences of such an assumption, while undetermined in this case, could be quite significant.

It was also assumed that once the enterprise mix for a farm had been selected, it was inflexible and each enterprise in the mix received its proportional share of any and all available water. This means that if a water shortage occurred, the farmers could not abandon one enterprise and use all of the available water on another.

To facilitate the operational determination of the net returns from the enterprises, it was assumed that if an enterprise normally required, for example, eight acre-inches of irrigation water in addition to normal rainfall, then the model allowed no more than eight acre-inches per acre of irrigation water to be applied to it.

Allocation of available water was assumed to be determined by the water requirements of the enterprises and the farmers' most profitable combinations of enterprises without regard to the planner's target level (T) or planned irrigated acres (I). Thus, the levels of the design variables T and I did not directly restrict the actual level of irrigation water application or the number of acres irrigated. The design variables did, however, affect the irrigation water allocation through their effect on the amount of water provided to the farms.[9]

The Simulation Study

The system was simulated for a factorial grid of levels of the system design variables R, I, and

[9] Since there is a positive correlation between rainfall and water inflow to the reservoir, an increase in I for a given value of T would cause a negative correlation between diversions for irrigation and inflow to the reservoir. This negative correlation would lead to optimal solutions for the system with small values for I and large values for T or, equivalently, for combinations of IT which tend to maximize the total water available for agricultural production and minimize the variance with which water is made available.

Burt has suggested an alternative formulation of the model in which I and T would be reduced to a single variable measuring total water available for agricultural production. This alternative formulation would eliminate the problem of inadequate consideration of rainfall in the model. It would also, however, necessitate alterations in the assumed reservoir management system and determination of the optimal system design.

T. All 320 combinations of the following levels were included:

$R=.06$, .12, .18, .24, and .30 (millions of acre-feet)
$T=40$, 44, 48, 52, 56, 60, 64, and 68 (inches of total water available per acre)
$I=6$, 8, 10, 12, 14, 16, 18, and 20 (thousands of acres to be irrigated).

Since a primary purpose of the study was to investigate the effects of different degrees of farmer risk aversion, it was necessary to repeat the entire simulation for various values of alpha. A relevant range of alpha values was obtained by trial and error through solving a risk programming problem for a typical dryland farm using various values of alpha until one was found where the farmers did not use all the land available to them. The alpha level thus obtained was .00006. This value was judged to be somewhat in excess of a realistic upper level of possible risk aversion since it was known that farmers in the area do utilize all of their available farm land under dryland farming conditions. Thus, an alpha of .00005 was used as the median point for this study. An alpha value of 0 was selected to depict a situation of no risk aversion, and a value of .0002 was selected to depict a high degree of risk aversion by farmers.

Near optimum systems for each of the three alpha values were determined by inspection of systems net benefits obtained by simulation.[4] The characteristics of these systems are summarized in Table 1. It is evident that optimum system size is not greatly affected by the degree of risk aversion. The lower target associated with the highest risk aversion constant reflects to some extent the desire of farmers for reliability in water delivery. The net benefits,[5] however, are more markedly affected by the degree of risk aversion than are the system parameters. Further discussions of the relationships of the system design variables and net benefits are found in Conner [2] and Conner *et al.* [3, 4].

[4] Near optimum systems refer to the particular levels of the design variables I, R, and T which were simulated and for which the calculated primary net benefits were the largest. Quadratic response surface analyses were performed in an attempt to identify the optima more precisely; however, they did not fit sufficiently well to justify using the results obtained.

[5] The annual primary net benefits are negative, indicating that annual costs of the system are larger than average annual primary benefits. If secondary benefits had been included, it is reasonable to assume that average annual total benefits would have been larger than annual costs.

Table 1. Optimum simulated systems

Level of risk aversion constant α	System design variables: T=Target inches/acre	I=Irrigation thousand acres	R=Reservoir thousand acre-feet	Primary net benefits thousand $
0	68	8	180	−17
.00005	68	8	180	−63
.0002	64	8	180	−78

Results

Reactions of the hypothetical farmers to the degree of certainty in irrigation water deliveries are reflected in the optimum combinations of crop enterprises they would choose under different circumstances. To examine the nature of these reactions, examples are presented at the near optimum reservoir size and for underbuilt and overbuilt systems.

Table 2 presents optimum enterprise programs for two irrigation systems found to be near optimum (Table 1). A 68 acre-inch water supply for 8,000 acres using a 180,000 acre-feet reservoir was found to be near optimum for alpha values of 0 and .0005. A 64 acre-inch target for the same number of acres and same size reservoir was found to be near optimum for an alpha of .0002.

The shift in cropping patterns associated with the level of risk aversion reflected by the alpha value is consistent with expected behavior.

Table 2. Optimum enterprises for two selected near optimal systems

Enterprise[a]	$ revenue/acre: Mean	Standard deviation	Near optimum programs with the following levels of risk aversion: 0	.00005	.0002
System: $T=68$, $I=8$, $R=180$					
Cotton—1	62.5	24.4		45.8	73.0
Cotton—2	70.1	32.1		13.2	
Cotton—3	82.0	56.1	73.0		
Sorghum—4	51.0	29.4	35.0		
Alfalfa	57.3	22.2	188.8	244.8	221.0
Total acres used[b]			333.3	333.3	330.5
System benefits ($1000)			−16.6[c]	−63.0[c]	−97.0
Farm revenue—mean ($)			18,590	17,820	17,230
Farm revenue—standard deviation			9,210	6,830	6,520
System: $T=64$, $I=8$, $R=180$					
Cotton—1	63.2	23.5		73.0	73.0
Cotton—3	85.6	51.5	73.0		
Sorghum—1	11.9	13.1	4.5	2.7	
Sorghum—4	53.3	26.7	128.8		
Alfalfa	58.9	19.9	88.3	219.7	219.7
Total acres used[b]			333.3	333.3	329.2
System benefits ($1000)			−28.7	−76.4	−78.3[c]
Farm revenue—mean ($)			18,370	17,580	17,548
Farm revenue—standard deviation			8,870	5,920	5,900

[a] Cotton 1 means cotton irrigated once, etc. Alfalfa is always irrigated.
[b] Each acre of cotton required an additional 0.5 acre of land for deferment to comply with the price support program. Each acre of dryland grain sorghum required an additional 0.5 acre for deferment to comply with standard production practices of the area, thus a simple total of acreages may not total 333.
[c] Most nearly optimum system.

In the case of no risk aversion, the farmer relies heavily on the highly irrigated, high risk enterprises of cotton and sorghum. As risk aversion increases, there is a shift to lower irrigation intensities with the alfalfa enterprise using the water made available in the process. Accompanying this shift is a trade-off between mean revenue and the standard deviation of revenues.

One interesting feature of all these enterprise programs is that while the optimal values of the system design variables indicate irrigation water will be provided for 133 acres per farm, or 8,000 of the available 20,000 acres, all available acreage is, in fact, irrigated. The total acreage is, however, irrigated at a less intensive rate than indicated by the optimal level of design variable T.

Investigation indicates that this difference between the planned and actual acres irrigated is largely the result of different patterns of deviations from the intended available moisture target for different irrigation plans. For example, the irrigation of 8,000 acres to the level of 68 inches available moisture requires approximately the same average annual irrigation water delivery as the irrigation of 16,000 acres to a level of 48 inches total moisture. However, the two irrigation plans will suffer different consequences, in terms of crop yields, because of deviations from the intended available moisture target. The more intensive irrigation level of 68 inches, with $I=8{,}000$, will more often result in the amount of total water available being larger than the target amount. This plan also results in few shortages, thus providing the largest and most reliable net returns from the farm enterprises.

Hypothetical farmer reaction to low and high risk situations is afforded by the examination of two systems which intend to deliver 68 acre-inches of available water for 8,000 acres but with different degrees of reliability. A 300,000 acre-feet reservoir provides a reliable water delivery while a 60,000 acre-feet reservoir provides an unreliable supply. The optimum crop enterprise combinations corresponding to the two systems are shown in Table 3. The existence of some crop yield variability for the overbuilt system causes farmers with a high aversion to risk ($\alpha=.0002$) to avoid the highly irrigated crops (cotton—3 and sorghum—4) despite the fact that the consequences in terms of average per acre net revenues foregone were relatively large. By comparing Tables 2 and 3 it can be seen that the enterprise combinations for the overbuilt system are quite similar to those for the optimum systems since the former provides water delivery only slightly more reliable.

Table 3. Optimum enterprises for two systems with low and high variation in water availability

Enterprise[a]	$ Revenue/Acre		Near optimum programs with the following levels of risk aversion:		
	Mean	Standard deviation	0	.00005	.0002
Overbuilt system: $T=68, I=8, R=300$					
Cotton—1	63.2	23.7			57.1
Cotton—2	71.4	30.8		66.7	
Cotton—3	85.6	52.5	73.0		
Sorghum—4	53.3	27.0	35.0		
Alfalfa	59.0	20.4	188.8	233.3	247.6
Total acres used[b]			333.3	333.3	333.3
System benefits ($1000)			−101.5	−145.2	−163.4
Farm revenue—mean ($)			19,252	18,524	18,221
Farm revenue—standard deviation			8,520	6,660	6,260
Underbuilt system: $T=68, I=8, R=60$					
Cotton—1	57.8	28.6		73.0	73.0
Cotton—2	61.7	39.1	66.7		
Sorghum—1	23.7	15.1			123.0
Alfalfa	46.0	33.3	233.3	223.8	
Total acres used[b]			333.3	333.3	232.5
Systems benefits ($1000)			−111.6	−131.2	−565.8
Farm revenue—mean ($)			14,848	14,515	7,133
Farm revenue—standard deviation			10,700	10,091	3,940

[a] Cotton 1 means cotton irrigated once, etc. Alfalfa is always irrigated.
[b] Each acre of cotton required an additional 0.5 acre of land for deferment to comply with the price support program. Each acre of dryland grain sorghum required an additional 0.5 acre for deferment to comply with standard production practices of the area, thus a simple total of acreages may not total 333.

In the underbuilt system, there is a substantial shift in cropping patterns associated with successively higher levels of risk aversion. The high risk situation in the underbuilt system is the only one examined in which alfalfa did not appear in the enterprise combination. In this case, once-irrigated sorghum largely replaces alfalfa because the mean and coefficient of variation of revenue from the crop are only slightly affected by the less reliable water deliveries provided by the underbuilt system. The absence of alfalfa from the enterprise combination had a substantial effect on the mean revenue.

Another feature of the underbuilt system is that even the risk-insensitive farmer tends to avoid highly irrigated enterprises. This is because the mean revenues of highly irrigated crops were quite low for this system.

Summary and Conclusions

This paper illustrates how water resource system models can be employed to incorporate the normative reaction of water users to risk into the process of determining the optimal level of system design variables. The results reported

here indicate that the inclusion of farmer reactions to risk had significant effects on both the system parameters and cropping plans. The study also indicates that the variability of water deliveries affects not only the variance but also the average income from an irrigated enterprise.

The effects of the extent of variation in water availability on enterprise choice and total farm income illustrates the importance of including farmer reaction to risk in a planning model. The difference in the risk reactions of farmers becomes more critical in terms of its influence on farm returns as water availabilities become more variable. The implication is that sensitivity to risk should be considered in evaluating the agricultural income producing potential of an investment in a water system.

References

[1] BATHKE, W. L., "Introduction of Hydrologic Risk Concepts to Optimization of Water Resource System Design," unpublished Ph.D. thesis, Texas A&M University, Aug. 1967.

[2] CONNER, J. R., "Incorporation of Agricultural Risk Into Water Resource Planning Models," unpublished Ph.D. thesis, Texas A&M University, Jan. 1970.

[3] ———, R. J. FREUND, AND M. R. GODWIN, "The Effect of Risk Taking by Users of Irrigation Water," Appendix 4, Final Report of Project C-1227-OWRR, Texas A&M University, Nov. 10, 1970.

[4] ———, "A Method for Incorporating Agricultural Risk Into A Water Resource System Planning Model," *Water Resources Bull.* 7:506–516, June 1971.

[5] FREUND, RUDOLF J., "The Introduction of Risk Into a Programming Model," *Econometrica* 24:253–262, July 1956.

[6] FRIEDMAN, MILTON, AND L. J. SAVAGE, "The Utility Analysis of Choices Involving Risk," *J. Polit. Econ.* 56:279–304, Aug. 1948.

[7] HARTLEY, H. O., AND R. R. HOCKING, "Convex Programming by Tangential Approximation," *Mgt. Sci.* 9:600–612, July 1963.

[8] HEIFNER, RICHARD G., "Determining Efficient Seasonal Grain Inventories: An Application of Quadratic Programming," *J. Farm Econ.* 48:648–660, Aug. 1966.

[9] JOHNSON, S. R., "A Re-examination of the Farm Diversification Problem," *J. Farm Econ.* 49:611–621, Aug. 1967.

[10] LAMOTTE, L. R., AND H. H. OXSPRING, "Convex: A Computer Program for the Hartley-Hocking Convex Programming Algorithm," Institute of Statistics, Texas A&M University, 1969, mimeo.

[11] MAASS, ARTHUR, MAYNARD M. HUFSCHMIDT, ROBERT DORFMAN, *et al.*, *Design of Water-Resource Systems*, Cambridge, Harvard University Press, 1962.

[12] MARKOWITZ, HARRY M., *Portfolio Selection: Efficient Diversification of Investments*, New York, John Wiley & Sons, Inc., 1959.

[13] MERRILL, WILLIAM C., "Alternative Programming Models Involving Uncertainty," *J. Farm Econ.* 47: 595–610, Aug. 1965.

[14] STOVALL, JOHN G., "Income Variation and Selection of Enterprises," *J. Farm Econ.* 48:1575–1579, Dec. 1966.

[15] TADROS, MAHFOUZ E., AND GEORGE L. CASLER, "A Game Theoretic Model for Farm Planning Under Uncertainty," *Am. J. Agr. Econ.* 51:1164–1167, Dec. 1969.

[16] U. S. Department of Interior, *San Angelo Project Colorado River Basin, Texas*, Washington, U. S. Government Printing Office, 1959.

[17] VON NEUMANN, JOHN, AND OSKAR MORGENSTERN, *Theory of Games and Economic Behavior*, 2nd ed., Princetón, Princeton University Press, 1947.

[18] ZUSMAN, PINHAS, AND AMOTZ AMIAD, "Simulation: A Tool for Farm Planning Under Conditions of Weather Uncertainty," *J. Farm Econ.* 47:574–594, Aug. 1965.

Asset Indivisibility and Investment Planning: An Application of Linear Programming*

PETER J. BARRY

A multi-period linear programming model is used to evaluate the effect of investments in indivisible land units on various measures of firm growth. Complete evaluation is found to depend upon the degree of asset indivisibility, the manager's planning horizon, and on the chosen financial or physical measures of growth.

INCORPORATING the effects of asset indivisibility in investment planning is a perplexing task. First, problems of generating sufficient cash and/or credit to meet financing terms for purchasing the indivisible asset may influence the rate of investment. Second, discontinuities in the supply function for indivisible assets indicate that large price changes may be required to warrant resource reallocations [10, 11]. This paper focuses on the first problem area by demonstrating the incorporation of asset indivisibility in a multi-period linear programming model and showing the effects of indivisibility on various measures of the firm's growth.

Methodology

A critical assumption underlying linear programming requires that all the firm's resources and products are perfectly divisible. Some integer programming techniques have been attempted with limited success in developing comprehensive and generally applicable models [7, 9, 16]. Simulation models [4, 12, 13] can also be readily adapted for asset indivisibility; however, they generally lack the optimization efficiency which is characteristic of mathematical programming techniques. Others have incorporated the effect of indivisibility in linear programming by only allowing investment activities at specified time intervals [8].

Linear programming can accommodate indivisibility by requiring the inclusion of the indivisible investment in the solution. This requirement, which is illustrated below, can be supported empirically when it contributes to the manager's objectives. Often specific objectives directed toward farm ownership, expansion of business size, and modernization of production systems are the means of obtaining an overall profit objective [6, 14].

A multi-period linear programming model was specified to portray farm decision making over a future 10-year period for a cash grain farmer [2, 3]. Decision-making elements (objectives, alternatives, constraints, technical coefficients) in this model are primarily oriented toward investment and financing problems rather than the more traditional production and marketing decisions. The objective function specified for the model farmer maximizes the present value of asset equity measured at the end of the 10-year planning period plus the present value of annual consumption during the planning period as specified by a reservation level of consumption and a declining marginal propensity to consume income increments above the reservation level.[1]

A primary expansion alternative for cash grain farmers in southwestern Ontario has been the purchase of additional land. The evaluation of prospective land investments should consider such factors as price, location, productivity, financing, and, in this case, size of sale unit. Farm land in the area has historically sold in indivisible units—generally 50 acres or some multiple thereof. Hence, an integer requirement is needed to evaluate properly this alternative in the planning model.

The method of integer requirement is outlined in Table 1. Activity X_j represents a land investment which, when required in the optimal solution in period t at the unit level, i.e., $B_{5t}=1$, will add 50 acres to the land-capital capacity of the firm as well as reduce cash and credit. Thus, the integer level of X_{jt} is determined by the level of B_{5t}. If, for example, $B_{5t}=2$, then X_{jt} will add 100 acres to land-capital capacity.

The appropriate integer level of X_{jt} is chosen by observing the level of X_{jt} in an optimal, non-

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PETER J. BARRY *is assistant professor of agricultural economics at Texas A&M University.*

[1] Present value of consumption is the sum of annual consumption discounted by the factor $1/(1+.08)^n$.

Table 1. Outline of a required land investment activity in a linear programming model

Activity	Land investment	Constraint	
Constraint	X_{jt}	Relation	Level
Objective	C_N	=	Z (Max)
Period t			
Cash	10	$\leq$	B_{1t}
Credit	40	$\leq$	B_{2t}
Land—capital	−50	$\leq$	B_{3t}
Profit	−5	$\leq$	B_{4t}
Integer—requirement	1	=	B_{5t}

integer solution and then requiring the activity at the first integer level below the optimum level.[2] Limits on available cash or credit preclude the feasibility of higher integer requirements. Alternatively, one could also determine the largest feasible level of X_{jt} by parametrically increasing the level of B_{5t} in integer units until an infeasible solution is obtained due to cash and credit limits, whereupon the highest feasible integer value of B_{5t} is required in the solution.

To determine the feasible rate of investment over the planning period, a multiple-run approach is used to purchase the largest amount of indivisible land units as rapidly as resources will permit. First, the land purchase activity is introduced without integer requirements only in year one. If less than 50 acres are purchased in the solution, the activity is removed from year one and reintroduced in year two. If more than 50 but less than 100 acres are purchased in year one, then a 50-acre purchase is required in year one. Similarly, a 100-acre purchase is required if more than 100 but less than 150 acres are purchased. Subsequent purchases in following years of the planning period are made as soon as sufficient resources, i.e., cash and credit, become available.

The case farmer is assumed to own 150 acres initially, all used in a corn-corn-soybeans rotation. This specification closely corresponds with empirical observation of crop production in southwestern Ontario [15]. The beginning capital structure is indicated in Table 2. Single-valued, constant expectations are specified for all costs, returns, and other production coefficients, except land values, which are expected to continue to appreciate. Based on historic crop budgets and summaries of farm records for the area, the use of operator labor and capital in the above crop rotation is assumed to yield about an 11.5 percent return on land investment, plus a 4 percent annual appreciation in land value.[3] When savings are not invested in land purchases, they are held either as cash in a non-interest bearing demand deposit or in a six-month time deposit at a 6 percent annual interest rate, or used to reduce real estate debt at 7.5 percent interest and non-real estate debt at 8.5 percent interest. Hence, from the standpoint of these cost and return data, one would expect the model solution to include purchases of land units whenever sufficient resources are available. Finally, the credit capacity of the firm may increase over time by virtue of income expectations from investments and as equity accumulates through debt repayment and appreciation in land value.

Results Derived from the Linear Programming Model

The evaluation of the impact of asset indivisibility on firm growth may differ depending on the measure of growth. Accordingly, the results are considered from the standpoint of physical measures, financial measures, and the planning horizon of the decision maker. Land indivisibility is treated with two variations: minimum-sized units of 50 and 100 acres.

Physical measures

Results (Table 2, Section A) obtained for optimal timing of land investments with 50-acre minimum purchases indicate that 200 acres can be purchased over the 10-year planning period. Thus, farm size more than doubles from 150 acres to 350 acres. The essential feature is the timing of land investments which indicates 50-acre purchases of land in years one, two, four, and nine. Cash, credit, and the land requirement are the primary limiting factors.

When land is assumed to be available for sale in minimum units of 100 acres (Section B), 200 acres are still purchased over the 10-year period. However, the timing of the investment is altered in that the 100-acre purchases occur in years three and eight, respectively. Thus,

[2] A discussion of similar approaches to integer requirements in linear programming for farm planning can be found in [1, 9, 17].

[3] Detailed crop budgets and other planning data are available in [2, 15]. This rate of return in production includes the contribution to earnings made by unpaid operator labor which was limited to use in crop production.

Table 2. Results of linear programming model with variations in minimum size of land purchase

	(Years) 0	1	2	3	4	5	6	7	8	9	10
A. 50-acre minimum											
Acres purchased		50	50	0	50	0	0	0	0	50	0
Acres farmed	150	200	250	250	300	300	300	300	300	350	350
Owner's equity, dollars	55,340	59,582	64,865	71,114	77,739	84,418	92,861	101,180	109,698	118,875	129,001
Annual consumption, dollars (average = $3852)		3,215	3,460	3,550	3,748	3,820	3,942	4,061	4,182	4,212	4,334
Minimum cash transfer, dollars		8,279	3,008	1,015	0	0	0	0	0	0	0
Minimum NRE credit reserve, dollars		50,009	26,845	36,030	13,447	14,127	13,044	14,517	15,714	1,015	0
Nonfarm investment, dollars		7,251	7,936	3,007	1,015	0	0	0	0	0	0
Equity: total assets	.598	.491	.433	.469	.415	.442	.472	.501	.528	.474	.501
B. 100-acre minimum											
Acres purchased		0	0	100	0	0	0	0	100	0	0
Acres farmed	150	150	150	250	250	250	250	250	350	350	350
Owner's equity, dollars	55,340	59,210	63,277	67,824	72,040	80,167	87,549	94,712	101,955	111,743	122,128
Annual consumption, dollars (average = $3704)		3,015	3,104	3,517	3,562	3,683	3,802	3,915	4,022	4,151	4,275
Minimum cash transfer, dollars		11,653	12,208	4,873	2,748	597	0	0	0	0	0
Minimum NRE credit reserve, dollars		68,559	68,559	26,489	33,014	38,870	41,826	40,550	8,708	4,473	0
Nonfarm investment, dollars		5,029	6,023	11,190	4,732	2,748	596	0	0	0	0
Equity: total assets	.598	.620	.639	.435	.462	.503	.535	.563	.415	.443	.470

following the 100-acre purchase in year three, five years are required for the manager to accumulate sufficient cash and credit resources to support the purchase of an additional 100 acres.

Financial measures

Financial measures of growth include asset equity and annual consumption—the specified objective function elements. In addition, measures of minimum cash transfers, minimum credit reserve, and equity-to-total asset ratios are indicated as important elements of the firm's liquidity position. As one might expect, the owner's equity at the end of the 10-year period and average annual consumption over the period are larger in the case where 50-acre purchases are possible. This occurs because the manager is able to acquire the use of land resources more rapidly. However, the relative significance of the differences in owner equity and annual consumption between the 50-acre and 100-acre purchases may not be either as large or as discontinuous as differences in timing of land purchase would suggest. The income and equity growth foregone from later acquisition of the 100-acre units of land are offset to some extent by increased income from the nonfarm investment and by reduction in costly short-term borrowing.

Also, the 100-acre purchases tend to increase firm liquidity, at least in early periods, through the larger use of cash transfers and nonfarm investments, higher minimum credit reserves, and slightly higher equity-to-total asset ratios over the 10-year period. While some seasonal cash transfers and non-farm investments are maintained during the first three to five years, in remaining periods all cash is used in short-, intermediate, and long-term debt repayment. Hence, it appears that individual decision makers need to pay as much attention to the impact of indivisibilities on the firm's liquidity position as on other measures of financial position.

Planning horizon

Results have been evaluated on the basis of a planning horizon of specified length; however, the relevant length of the planning horizon may be quite important, particularly when there are large differences in indivisibilities among investment alternatives. An economically relevant planning horizon is suggested as the planning time needed in order to make a decision for the first period [5]. As implied by the "turnpike theorem," a sufficiently long horizon leads to a von Neumann path of optimal and constant rate of growth. Yet the irregular acquisition of assets arising from asset indivisibility, as indicated above, tends to modify the constant rate of growth proposition and at the least calls for a longer planning horizon to evaluate the effects of these indivisibilities. While it is apparent that the relative size of results in Table 2 differs for periods of less than 10 years, one can also expect results to differ for periods longer than 10 years. However, while longer horizons are not tested in the model, the discounting process implies the declining economic importance at present of variations in timing of distant investments.

It is also quite likely that the economically relevant planning horizon will differ from the manager's subjectively relevant horizon due primarily to risk preferences. Hopefully, accurate and comprehensive forward planning

will reduce this difference and dispel the tendency of risk and uncertainty to shorten planning horizons.

Concluding Comments

The results of this study illustrate one approach to the use of linear programming in evaluating the effect of asset indivisibility on timing of investment and firm growth. It is even quite plausible that the allocation of resources between investment alternatives differing in both expected profits and degree of asset indivisibility could be influenced by rate of acquisition of these assets. Given an effective capital constraint, expansion might occur with less divisible assets even though profit possibilities appear more favorable with the others, simply because the less divisible assets could be more rapidly acquired.[4]

Efforts to reduce indivisibilities may have a high payoff. The prospective purchaser of land, for example, might be well advised to seek purchases of land in the smallest possible size of unit—assuming that operating efficiency is not severely impaired. This behavior will enable him more rapidly to overcome capital constraints, receive income from the acquired land, and add to equity for later purchases. Similarly, the prospective seller of land may find that buyers are more readily available for the sale of several small-sized units rather than one large unit. However, in addition to indivisibility, several other factors in the land market may also introduce uncertainties which impede investment planning. Investment timing as indicated by model outcomes was contingent upon land becoming available for sale at the right time, location, price, quality, and size of unit. All these factors are subject to variation. The manager who expects to purchase 50 acres five years in the future may find his plans stymied if there are no suitably priced 50-acre units for sale within a feasible distance.

In a similar vein, future changes in technology may influence the cost, size, and type of non-real estate investment, thereby complicating investment planning. These effects are not all negative, however. Several opportunities exist for alleviating the irregular purchases of indivisible items. Often the manager may choose between different sizes of equipment, buildings, and machinery. Although the range of choices is limited, new technology may generate a wider range in the future. In addition, alternative financial strategies contribute flexibility to investment planning. Non-ownership means of acquiring the annual services of durables—land rental and custom hiring—have become very important means of reducing the irregularity of purchase which is associated with ownership and large equity capital requirements. The future growth of the service hiring route may depend greatly on the extent to which other financing alternatives can reduce these high ownership-capital requirements. For example, expansion in lender limits on maximum loans and other loan terms, which ease pressure on a firm's cash flow, may serve to enlarge borrowing capacity and provide for easier purchases of indivisible assets.

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[4] An interesting analogy of the influence of asset indivisibility and capital constraints arises in the case of money market instruments. One reason that small investors are inclined to invest their savings in bank savings accounts or perhaps E bonds rather than high yielding corporate bonds or government securities is the large denominations (indivisibility) in which these latter instruments are issued.

References

[1] ACTON, R. W., "Computer Assistance for Farm Investment Decisions," unpublished Ph.D. thesis, Purdue University, 1970.

[2] BARRY, PETER J., *Financial Analysis of Expansion Alternatives for Cash Grain Farms in Ontario*, School of Agricultural Economics and Extension Education, University of Guelph, Pub. No. AE/71/6, July 1971.

[3] ———, AND C. B. BAKER, "Reservation Prices on Credit Use: A Measure of Response to Uncertainty," *Am. J. Agr. Econ.* 53:222–227, May 1971.

[4] BOEHLJE, M. D., "Strategies for the Creation and Transfer of the Farm Firm Estimate," unpublished Ph.D. thesis, Purdue University, 1971.

[5] BOUSSARD, JEAN-MARC, "Time Horizon, Objective Function, and Uncertainty in a Multiperiod Model of Firm Growth," *Am. J. Agr. Econ.* 53:467–477, Aug. 1971.

[6] CANDLER, WILFRED, AND MICHAEL BOEHLJE, "Use of Linear Programming in Capital Budgeting with Multiple Goals," *Am. J. Agr. Econ.* 53:325–330, May 1971.

[7] COLYER, D., "A Capital Budgeting, Mixed Integer, Programming Model," *Canadian J. Agr. Econ.* 16: 1–7, Feb. 1968.

[8] DUVICK, R. D., "Alternative Methods of Financing Growth on Michigan Dairy Farms," unpublished Ph.D. thesis, Michigan State University, 1970.

[9] EDWARDS, CLARK, "Using Discrete Programming," *Agr. Econ. Res.* 15:49–60, April 1963.

[10] ———, "Resource Fixity and Farm Organization," *J. Farm Econ.* 41:747–759, Nov. 1959.

[11] JOHNSON, GLENN, "Supply Function—Some Facts and Notions," in *Agricultural Adjustment Problems in a Growing Economy*, ed., Earl O. Heady, *et al.*, Ames, Iowa State College Press, 1958, Ch. 5.

[12] LEE, F. E., "Exploitation of Information for Capital Accumulation Under Uncertainty," unpublished Ph.D. thesis, Purdue University, 1971.

[13] LINS, DAVID A., "An Empirical Comparison of Simulation and Recursive Linear Programming Firm Growth Models," *Agr. Econ. Res.* 21:7–12, Jan. 1969.

[14] NIELSON, JAMES, *The Michigan Township Extension Experiment: The Farm Families—Their Attitudes, Goals and Goal Achievement*, Michigan Agr. Exp. Sta. Tech. Bull. 287, 1962.

[15] Ontario Department of Agriculture and Food, *Summary Report, Ontario Farm Management and Accounting Project*, University of Guelph, 1969.

[16] WEIGARTNER, MARTIN H., *Mathematical Programming and the Analysis of Capital Budgeting Problems*, Englewood Cliffs, N.J., Prentice-Hall, Inc., 1963.

[17] WEINSCHENK, G., "Recent Developments in Quantitative Analysis at the Micro Level," in *Economic Models and Quantitative Methods for Decisions and Planning in Agriculture*, ed., E. O. Heady, Ames, Iowa State University Press, 1971, Ch. 8.

Separable Programming for Considering Risk in Farm Planning*

Wayne Thomas, Leroy Blakeslee, LeRoy Rogers, and Norman Whittlesey

This paper proposes use of separable programming for selecting farm enterprises which are efficient in terms of expected income and income variance. An empirical application on a crop-livestock farm in the Columbia Basin of Washington is presented. The effects of removing statistically insignificant covariance terms and the error introduced by the linear approximation are explored.

Markowitz [6, 7] has written on the general theory of decision making where both expected returns and risk are to be considered. His work provides a framework for analyzing farmer decisions in circumstances where income variance is introduced as a measure of risk. Production and market processes that confront producers yield an efficiency frontier relating income variance and expected income. A hypothetical efficiency frontier (Fig. 1) shows that increases in expected income are possible only with increases in income variance. The curve represents a series of points of maximized net income for each level of net income variance. Any point to the left of the efficiency curve represents an inferior organization in that it does not maximize net income for that specific level of income variance. All points to the right of the efficiency frontier are infeasible. The optimal organization of a farm business lies somewhere on this "efficiency frontier." The exact position depends upon the individual's preference for expected income and income variance.

Markowitz, among others, has suggested the use of quadratic programming for developing "efficient" plans that minimize variance for a given level of expected returns. Hazell [3] recently criticized quadratic programming on the basis of uncertain performance from existing algorithms. As a more easily computed substitute, he proposed use of the expected income-mean absolute income deviation-criterion, which can be solved by parametric linear programming procedures.

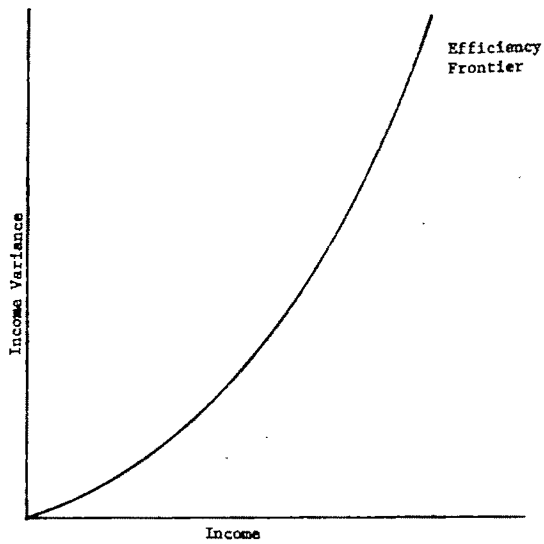

Figure 1. Hypothetical efficiency frontier relating income and income variance

Hazell's approach has considerable appeal, and in many applications the simplification of the computation is a decided advantage over quadratic programming. Hazell's method does have limitations, however, as he has noted. The most important is that the variance-covariance structure of gross margins must be represented in terms of a specific set of sample observations on margins. Subjective information on the variance-covariance structure may be introduced but only by creating and using a "pseudo-sample" that reflects the desired structure. Hazell also notes that though the mean absolute deviation can be used as a substitute for the variance in deriving efficient income-variance farm plans, the resulting estimate of the population standard deviation will be no more than 88 percent as efficient as an estimate based on the sample variance.

In this paper estimates of income variance are used to incorporate risk into selection of enterprises on a representative farm unit in the

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Wayne Thomas, *former Washington State University graduate student, is assistant professor of agricultural economics at the University of Alaska.* Leroy Blakeslee *is assistant professor and* LeRoy Rogers *and* Norman Whittlesey *are associate professors in the Department of Agricultural Economics, Washington State University.*

Columbia Basin of Washington. Separable programming is used to determine the efficiency frontier, though the problem is formulated somewhat differently from the approach of Markowitz.[1] Separable programming is highly operational on computers currently accessible to most researchers. Computing experience with the practical-sized problems of this study has been most satisfactory.

Minimizing Variance Versus Maximizing Expected Income

Consider the following two problems in which the technology of production is represented linearly:

I. Maximize

$$z = C_1'X_1 + C_2'X_2 \tag{1}$$

Subject to

$$A_1X_1 + A_2X_2 \leq B \tag{2}$$

$$X_1'QX_1 \leq v \tag{3}$$

for

$$0 < v < v_{\max}$$

$$X_1, X_2 \geq 0$$

II.[2] Maximize

$$-v = -X_1'QX_1 \tag{4}$$

Subject to

$$A_1X_1 + A_2X_2 \leq B \tag{5}$$

$$-C_1'X_1 - C_2'X_2 \leq -z \tag{6}$$

for

$$z_{\min} < z < z_{\max}$$

$$X_1, X_2 \geq 0$$

where

- X_1 is a vector of processes for which unit contributions to profit are random,
- X_2 is a vector of processes for which unit contributions to profit are deterministic,
- A_1 and A_2 are matrices of constants specifying unit resource requirements,
- B is a vector of resource availabilities,
- C_1 is a vector of expected unit returns for processes in X_1,
- C_2 is a vector of known unit returns for processes in X_2,
- Q is a positive definite symmetric matrix with elements that are variances and covariances of unit returns for processes in X_1,
- z is expected profits,
- v is the variance of profits,
- $v_{\max}$ is the variance level above which no further changes occur in the optimum X_1, X_2 as v is varied parametrically in problem I,
- $z_{\min}$ is the maximum income that can be generated with X_2 processes (i.e., the optimum z in problem I when $v=0$),
- $z_{\max}$ is the income level above which no feasible solutions exist as z is varied parametrically in problem II.

An exact correspondence exists between the set of all optimum solutions to problem I and the set of all optimum solutions to problem II. This may be proved by (1) noting that the Kuhn-Tucker conditions are both necessary and sufficient for optimum solutions to both problems;[3] (2) determining the explicit Kuhn-Tucker conditions for problems I and II; (3) observing that the optimality of X_1^*, X_2^*, z^* as a solution to problem I implies the existence of Lagrangian multipliers satisfying the Kuhn-Tucker conditions for model II at X_1^*, X_2^* and with $z=z^*$ on the right-hand side of (6). This argument holds for any v in $0<v<v_{\max}$. Therefore, every optimum solution to problem I has its counterpart among the optimum solutions to problem II. A parallel argument can be developed to show that every solution to problem II has its counterpart among the set of optimum solutions to problem I. Hence, the two sets are identical.[4]

Problem II above will be recognized as the one suggested by Markowitz, and available quadratic programming algorithms may be used to find solutions. The IBM separable programming[5] procedure for solving a linearized approximating problem is outlined in the next section.

[1] The IBM separable programming algorithm can also be used to solve the problem as formulated by Markowitz.

[2] Note that maximizing $-v$ is equivalent to minimizing v, and $-C_1'X_1-C_2'X_2\leq -z$ is equivalent to $C_1'X_1+C_2'X_2\geq z$.

[3] See Hillier and Lieberman [4, pp. 575–576].

[4] This conclusion holds only over the range of z and v given in the specification of problems (1) and (2). However, the ranges given include all of the efficiency frontier which is of any real interest.

[5] See Beale [1] or Hadley [2] for a full discussion of algorithms. The IBM program makes use of what Hadley terms "the δ-form of the approximating problem."

Application of Procedure

Crop farmers in the irrigated farming area of the Columbia Basin of Washington have expressed interest in adding livestock to their farming system. A major concern was that in addition to increasing profits, the enterprise combination should not result in unduly large income variance. To assess this possibility, a linear-separable programming model was developed for a representative 160-acre farm. Expected income was maximized subject to appropriate physical and financial constraints and an upper bound on income variance. The possible crop options available in the model were wheat, sugar beets, potatoes, alfalfa, and corn silage. The livestock production possibilities were calf production with a cow-calf system, yearling production with a cow-yearling system, cattle finishing, stocker cattle feeding, slaughter lamb production with a farm flock of ewes, and hog production with a quarterly farrowing system.

The problem is readily recognized as an ordinary linear programming problem except for the nonlinear characteristics of the income variance constraint. The variance constraint was of the form

$$\sum_j \sigma_j^2 X_j^2 + 2 \sum_{j<k} \sigma_{jk} X_j X_k \leq V^T. \tag{7}$$

In this formulation of the variance constraint, σ_j^2 is the variance of annual income from the jth enterprise, X_j is the jth activity level, σ_{jk} is the covariance between the annual incomes of the jth and kth enterprises, and V^T is the variance.

In general, separable programming provides a technique for approximating a nonlinear constraint or objective function so long as it can be represented as a sum or difference of nonlinear functions of single arguments. The variance constraint, equation (7), can be written in this form if, corresponding to each nonzero covariance term, two new variables z_{jk1} and z_{jk2} are defined as in (8),

$$\begin{aligned} z_{jk1} &= 1/2(X_j + X_k) \\ z_{jk2} &= 1/2(X_j - X_k) \end{aligned} \tag{8}$$

and then use is made of the identity (9),

$$\sigma_{jk} X_j X_k \equiv \sigma_{jk}(z_{jk1}^2 - z_{jk2}^2). \tag{9}$$

In the revised formulation, equations (8) are added as additional constraints to the problem and (9) is substituted into (7) to get (10), a form which can be accommodated with separable programming techniques.

$$\sum_j \sigma_j^2 X_j^2 + 2 \sum_{j<k} \sigma_{jk} z_{jk1}^2 - 2 \sum_{j<k} \sigma_{jk} z_{jk2}^2 \leq V^T. \tag{10}$$

Each of the separable, nonlinear functions on the left-hand side of (10) was then replaced by a piecewise linear approximation, and the separable programming mode of an IBM-supplied program, MPS/360, Linear and Separable Programming, was used to do the computations on an IBM 360/67 Computer [5].

In this model, net income variance for each enterprise was based upon time-series data for actual yields and prices obtained in the study area from 1950 to 1969.

Results were obtained from the programming model with two sets of variance-covariance coefficients. The first set included a covariance term for all combinations of activities where the sign of the covariance term was consistent with economic logic. The second set included only covariance terms showing correctness of sign and 90 percent level of statistical significance. A "t" test was used to test the significance of each covariance term. Specifically, the correlation coefficient for each pair of net income series was tested and, if found significant, the corresponding covariance term was judged significant. Out of a possible 55 covariance terms, only the following six with their associated correlation coefficients were deemed significantly different from zero: sugar beets-spring stocker cattle (−.477), alfalfa-corn silage (.509), spring stocker cattle-summer finished cattle (.511), sugar beets-fall stocker cattle (.383), alfalfa-lambs (−.412), and corn silage-spring stocker cattle (−.436). Model solutions were obtained for both the all-covariance and significant covariance cases with the variance constraint ranging from very low levels to a point of being nonconstraining.

Results

Enterprise organizations shown in Table 1 resulted from the model that included all-covariance terms. Under the unlimited variance situation, high income producing enterprises dominated the organization. Potatoes, sugar beets, and cattle feeding, traditionally high

Table 1. Optimal enterprise organization at various levels of income variance using all-covariance terms

	Net farm income variance[a] (millions of dollars)						
	Unlimited	35	30	25	20	15	10
Crop enterprise (acres)							
Alfalfa	0	0	0	0	0	0	0
Corn silage	0	0	0	0	0	0	0
Wheat	80	81	85	89	95	100	100
Potatoes	40	39	35	31	25	20	10
Sugar beets	40	40	40	40	40	40	40
Livestock enterprise (head)							
Winter finished cattle	100	100	100	100	100	100	89
Summer finished cattle	58	84	79	74	75	72	72
Aftermath stocker cattle	90	100	100	100	100	100	100
Lambs[b]	147	112	131	150	169	162	146
Hogs[b]	16	16	16	16	16	16	16
Objective function value	$21,839	$21,661	$21,330	$21,004	$20,452	$19,823	$18,511

[a] Highest net farm income variance was $38,719,090.
[b] These figures were the number of ewes and sows in the respective production activities.

income and high risk enterprises, were all at maximum levels permitted by production constraints.

The first enterprise to experience reduced production as the income variance constraint became effective was potatoes. This resulted from the substantial income variance associated with potato production (Table 2). Wheat, a rather stable enterprise, replaced the acreage previously devoted to potatoes until the most restrictive of variance levels was imposed; then a small acreage of corn for silage entered the solution. Among the livestock enterprises, hog numbers were particularly stable, remaining at their upper bound under all situations. Cattle and lamb numbers varied slightly at different income variance levels, but the changes were minor.

Profits for the farm were sensitive to the limitation on income variance. The most restrictive income variance situation reduced net farm income 15 percent below the unlimited variance organization. This income reduction was largely the result of substitution of stable wheat for high risk potato production.

Results of the model that included only the six significant covariance terms are shown in Table 3. The increased sensitivity of the model to imposition of restraints on income variance is readily apparent. Twenty-seven of the 30 negative covariance terms existing in the first model were no longer available to reduce total variance. The inability to retain high income crops (e.g., potatoes) in the solution resulted in a more rapid drop in firm profits as increasingly restrictive variance limitations were imposed.

Wheat initially replaced potatoes in the crop organization as with the all-covariance model. However, as permitted income variance levels were reduced, corn silage and alfalfa began to replace wheat. Corn silage and alfalfa were involved in two of the three significant negative covariance terms retained in the model. Twenty acres of cropland were actually idled under the most restrictive variance situation. Cattle feeding was the livestock enterprise most sensitive

Table 2. Income variance-covariance matrix between enterprises

Enterprise	Unit	Enterprise: Wheat	Potatoes	Sugar beets	Alfalfa	Corn silage	Hogs	Lambs	Spring stocker cattle	Fall stocker cattle	Summer finished cattle	Winter finished cattle
Wheat	Ac	580.7	− 742.4	268.4	10.4	78.6	− 13.0	− 14.8	− 98.6	− 24.6	− 77.5	−113.1
Potatoes	Ac		21,520.7	−474.2	415.8	1,316.6	−102.0	182.0	645.1	−239.8	− 45.5	−539.5
Sugar beets	Ac			984.7	5.6	222.4	3.6	41.2	−241.1	113.6	− 37.3	−111.7
Alfalfa	Ac				222.6	197.1	− 9.7	− 23.2	15.1	15.8	− 1.0	− 25.3
Corn silage	Ac					587.6	− 9.5	17.4	−120.8	− 7.0	−110.4	− 49.5
Slaughter hogs	Hd						35.9	6.0	− 14.2	3.1	− 16.9	− 23.2
Slaughter lambs	Hd							14.3	2.3	12.4	− 6.0	− 20.3
Spring stocker cattle	Hd								259.5	53.9	106.3	− 37.8
Fall stocker cattle	Hd									89.3	26.2	4.6
Summer finished cattle	Hd										166.8	47.9
Winter finished cattle	Hd											276.9

Table 3. Optimal enterprise organization at various levels of income variance using only significant covariances

	Net farm income variance[a] (millions of dollars)									
	Unlimited	45	40	35	30	25	20	15	10	5[c]
Crop enterprise (acres)										
Alfalfa	0	0	0	0	0	0	0	0	9	20
Corn silage	0	0	0	0	1	6	20	30	40	40
Wheat	80	82	86	90	94	94	80	77	61	41
Potatoes	40	38	34	30	25	20	20	13	10	0
Sugar beets	40	40	40	40	40	40	40	40	40	40
Livestock enterprise (head)										
Winter finished cattle	100	100	100	100	100	100	36	40	0	0
Summer finished cattle	58	61	64	68	70	69	71	60	30	4
Aftermath stocker cattle	90	92	95	98	100	100	84	81	66	63
Lambs[b]	147	152	159	164	169	169	169	169	169	102
Hogs[b]	16	16	16	16	16	16	16	16	16	16
Objective function value	$21,839	$21,648	$21,320	$20,972	$20,441	$19,886	$19,253	$18,354	$17,200	$14,259

[a] Highest net farm income variance was $47,954,060.
[b] These figures were the number of ewes and sows in the respective production activities.
[c] Idle land totaled 20 acres.

to reduction in permitted levels of variance. This is consistent with the high risk in cattle feeding.

When only the significant covariance terms were used, the variance became effective at a much higher income. The income variance constraint was limiting at a net income standard deviation of $6,708 for the significant covariance model, but was nonconstraining until a standard deviation of $5,916 for the all-covariance model. In general, the enterprise organization remained rather constant until the constraint level restricted variability in net income to a standard deviation of approximately $5,000.

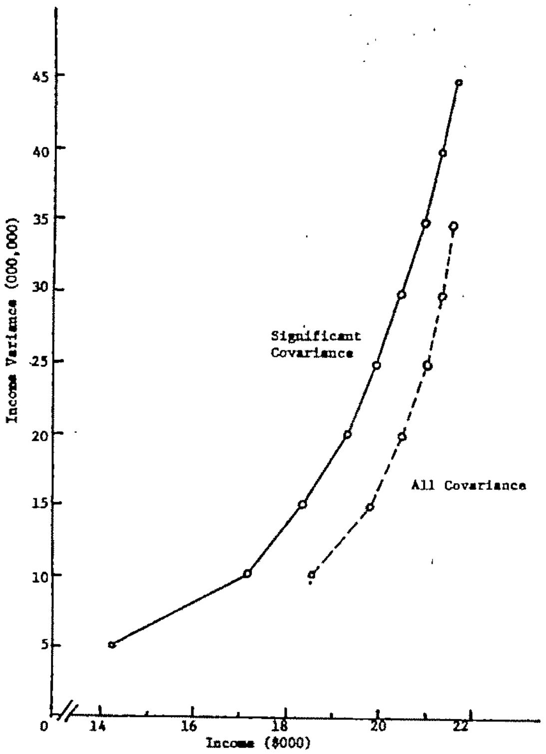

Figure 2. Efficiency frontier for all and significant covariance models

Comparison of all-covariance and significant covariance models

As mentioned, the significant covariance model yielded lower expected incomes for each permitted level of income variance. The difference between the two models is illustrated by the efficiency frontiers in Figure 2 and the objective function values in Table 4.

Selection of the model using only significant

Table 4. Standard deviations for various income levels

Income variance	Standard deviation	Level of Income: All-covariance model	Level of Income: Significant covariance model
Unlimited	—	$21,839	$21,839
45,000,000	$6,708	21,839	21,648
40,000,000	6,325	21,839	21,320
35,000,000	5,916	21,661	20,972
30,000,000	5,477	21,330	20,441
25,000,000	5,000	21,004	19,886
20,000,000	4,472	20,452	19,253
15,000,000	3,873	19,823	18,354
10,000,000	3,162	18,511	17,200
5,000,000	2,236	—[a]	14,259

[a] Information not available because of matrix inversion problems below 10,000,000 variance.

covariance terms has an intuitive appeal, but determination of the appropriate level of significance remains a problem. The influence of model choice upon computation time and the error in approximating the nonlinear relationships were examined in this study.

Using separable programming, representation of the variance-covariance structure of the all-covariance model required 121 rows and 499 columns. About $3\frac{1}{2}$ minutes of computer center processing unit time were required to determine the set of optimum solutions generated by parametrically varying the right-hand side of the variance constraint. The variance-covariance structure of the significant covariance model required 23 rows and 93 columns and only 50 seconds to optimize. Removal of 49 nonsignificant covariance terms markedly reduced matrix size and computer time requirements.[6]

Of course, the results given in Tables 1, 3, 4 relate to the approximating problem. How accurately linear representations of variance and covariance in the two models approximate the quadratic form given in equation (7) is important in the choice of model. This comparison was made by evaluating the actual quadratic form given in equation (7) using the amount of each crop and livestock enterprise in the optimal solution to the approximating problem at each level of income variance. Data in Table 5 suggest that both the all-covariance model and the significant covariance model were reasonably accurate. Using the separable constraint level as the base, errors in the all-covariance model ranged from less than 1 percent to 3 per cent, and in the significant covariance model, from less than 1 percent to 6 percent. Considering the possibility of error reduction through grid refinement, there is little basis for choice between the two models based on relative error in representing the variance-covariance relationship.

Table 5. **Difference between level of variance specified in separable constraint and actual income variance**

Separable constraint variance Level	All-covariance model		Significant covariance model	
	Actual variance[a]	Percent error	Actual variance[a]	Percent error
45,000,000	—	—	44,333,534	1
40,000,000	—	—	39,142,125	2
35,000,000	34,763,418	1	34,608,418	1
30,000,000	29,437,367	2	29,077,501	3
25,000,000	25,045,797	—[b]	24,413,596	2
20,000,000	19,738,108	1	19,436,339	3
15,000,000	15,419,995	3	14,036,846	6
10,000,000	9,944,316	1	9,608,115	4
5,000,000	—[c]	—	4,980,386	—[b]

[a] Calculated using Eqn (7).
[b] Less than .5 percent.
[c] Not available due to matrix inversion difficulties.

The results from the two models do not differ much. Therefore, the computation savings associated with the significant covariance model rule in its favor. Not only was computer time reduced 76 percent, but selection of the significant covariance model would have eliminated calculation of the numerous grids for nonsignificant covariance terms.

Conclusions

Studies of the type reported in this article add another useful dimension to managers' decisions. Reporting the standard deviations as sociated with net incomes from particular optimal enterprise organizations should be useful to farm operators. Lenders and others who help farmers should find this information useful in appraising various financial strategies.

Separable programming offers an operational alternative for incorporating both expected income and income variance into enterprise selection. This is particularly true in cases where the number of nonzero covariance terms is small, as may well be the case in many agricultural applications.

[6] No attempt was made to solve these problems by quadratic programming. However, a computer code for quaratic programming based on Wolfe's algorithm has been used in other research at Washington State University. The following representative optimization times may be of interest: 3 separate problems with 9–10 rows required an average of 38 seconds CPU time; 4 problems with 18 rows averaged 71 seconds each; 1 problem with 20 rows required 202 seconds; and 1 problem with 27 rows required 96 seconds. A single solution was found in each case. Had we used quadratic programming in the present case, the problem would have had 35 rows.

References

[1] BEALE, E., *Mathematical Programming in Practice*, New York, John Wiley & Sons, Inc., 1968.

[2] HADLEY, G., *Nonlinear and Dynamic Programming*, Reading, Mass., Addison-Wesley Publishing Co., Inc., 1964.

[3] HAZELL, P. B. R., "A Linear Alternative to Quadratic and Semivariance Programming for Farm Planning Under Uncertainty," *Am. J. Agr. Econ.* 53:53–62,

Feb. 1971.

[4] HILLIER, FREDERICK S., AND GERALD J. LIEBERMAN, *Introduction to Operations Research*, San Francisco, Holden-Day, Inc., 1967.

[5] International Business Machine Corporation, *Mathematical Programming System 360, Version 2, Linear and Separable Programming—User Manual*, White Plains, N.Y., 1968, Ch. 5.

[6] MARKOWITZ, H., "Portfolio Selection," *J. Finance* 12:77–91, March 1952.

[7] ———, *Portfolio Selection, Efficient Diversification of Investments*, New York, John Wiley & Sons, Inc., 1959.

Shift-Share Analysis as a Technique in Rural Development Research*

Wayne C. Curtis

This note presents a technique for delineating changes in income and employment dimensions of rural counties or similar units. Shift-share analysis is portrayed as a descriptive tool with potential use in rural development research. A model to isolate sectoral income and employment changes in four rural counties is briefly discussed.

Within recent months there has been a concerted effort toward solving the problems of economic development of rural areas. Continued emphasis in this direction will necessitate expansion of existing research techniques and development of new ones. Emerging techniques will have to be adopted to solve development problems not only at the state and regional levels but also in county and multicounty areas.

The purpose of this note is to apply an existing technique to problems of delineating changes in the income and employment dimensions of the economies of rural counties or similar units. Since income and employment are such vital factors in the overall economic development of an area, some means of quantitatively assessing changes in both factors must be developed. If shifts in income and employment can be isolated, they can be used to explain partially structural transformations in the economy and to provide possible insight into the future direction of economic development and growth. One technique for isolating the various factors associated with income and employment changes is the *shift-share model.*

The shift-share technique has been used to examine variations in both employment [3, 4, 12] and income [6], while modifications of the technique have appeared in other studies [11, 13]. Within the past decade this model has been used primarily to compare state and regional growth rates with those of the nation. In these earlier studies, attention has been focused on either the income or employment dimension. The approach presented here considers a simultaneous treatment of both income and employment changes for county and multi-county units. It also represents the first attempt to the author's knowledge to perform shift-share analysis of income changes at the county level.

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Wayne C. Curtis *is assistant professor of agricultural economics at Auburn University.*

Shift-Share Model[1]

Shift-share analysis may be used to separate an area's income and employment growth into three factors and to measure the contribution of each. Although it does not provide basic answers to changes in composition of income and employment, the technique does provide a useful framework for tracing causes and effects of such trends. As Ashby [5] has pointed out, an in-depth explanation of these changes is beyond the scope of the shift-share technique.

Growth effects

The initial step in identifying factors responsible for variations in income and employment changes is to separate the total growth increment into three effects: national growth, industrial mix, and regional share. The national growth effect measures the overall growth of the national economy. This effect is calculated by applying to each income or employment component in the base year the change in total income or employment between the base year and the terminal year. National growth must be isolated in order to focus on the two remaining effects which account for differences in regional growth patterns.

The industrial mix effect, called the component mix effect when referring to income changes, results from differences between the income or employment structure of an area and of the nation. It is estimated by applying to each income or employment component in the base year the difference between the national rate for that component and the overall national growth rate. If the former is larger, the particular component is a rapid growth component. Its presence in the economy gives rise to area growth; the size of the increase will vary

[1] A more extensive description of the principal aspects of the shift-share model is presented in [6, pp. 17–18] and [3, pp. 14–15].

according to the relative proportion of the component located in the area. On the other hand, where the national growth rate of an industry is less than the national rate for all industries, it is termed a slow growth component and it has a negative effect on income and employment. Again, this effect is a relative one.

The third element of an area's growth is the regional share effect, the second factor accounting for a differential change between an area and the nation. To calculate this element, the difference between the percentage change in each income or employment component in the area and percentage change in the same component nationally is applied to the area component in the base year. The regional share effect portrays the competitive position of an area in relation to the rest of the nation. For instance, an employment component that is growing faster in an area than its counterparts in the nation as a whole will add to the area's overall growth relative to that of the nation, while a slower growing component will bring forth an opposite effect. That is, a positive difference signifies a shift in the particular component into the area; a negative difference indicates a shift out of the area.

Mathematical formulation

Shift-share analysis can be stated mathematically in the following terms:

$$\text{(1)} \quad \sum_{i=1}^{m} \sum_{j=1}^{n} X_{ij} = X_{oo}$$

$$\text{(2)} \quad \Delta X_{ij} = [X_{ij}(t) - X_{ij}(o)]$$

$$\text{(3)} \quad e_{oo} = [X_{oo}(t) - X_{oo}(o)] \mid X_{oo}(o)$$

$$\text{(4)} \quad e_{io} = [X_{io}(t) - X_{io}(o)] \mid X_{io}(o)$$

$$\text{(5)} \quad e_{ij} = [X_{ij}(t) - X_{ij}(o)] \mid X_{ij}(o)$$

$$\text{(6)} \quad \Delta X_{ij} = [X_{ij}(o)][e_{oo}] + [X_{ij}(o)][e_{io} - e_{oo}] + [X_{ij}(o)][e_{ij} - e_{io}]$$

where

X_{ij} = employment or income component i in area j at any given time

$X_{ij}(o)$ = employment or income component i in area j at an initial time point, o

$X_{ij}(t)$ = employment or income component i in area j at a terminal time point, t

X_{oo} = national or aggregate employment or income in all components at any given time

X_{io} = national or aggregate employment or income in component i at any given time

e_{oo} = national growth effect

e_{io} = industrial mix effect

e_{ij} = regional share effect.

Application

Shift-share analysis was used to isolate changes in income and employment from 1960 to 1969 in four low income, rural Alabama counties. Primary purpose of the analysis was to identify the structural transformation of these economies in terms of the income and employment dimensions. All firms in the area were aggregated into 10 sectors based on the Bureau of Labor Statistics classification scheme; county income and employment data were obtained from estimates published by state agencies.[2]

Results of the analysis are briefly summarized in Tables 1 and 2. Detailed analysis by county is reported in [10, pp. 15–23]. In Table 1, aggregate and sectorial income changes occurring throughout the four counties have been separated into the three shift components. The national growth effect for the area accounted for about 94 percent of the increase in total personal income during the period under analysis. The component mix effect did not explain a large percentage of the change in income in the study area counties—about 3 percent of the total change or approximately −\$3.1 million. That the component mix effect was negative can be interpreted to mean that the area's mix of income producing activities was composed more of the slow growing components nationally rather than the rapid growing ones. Regional share, the third component of the shift-share model, accounted for about 9 percent of the total income change or \$9.6 million. Greatest regional share impact was in the manufacturing sector. Income generated by manufacturing firms grew at a more rapid rate than that generated by like firms nationally, adding \$4.6 million to the competitive position of this sector. Wages and salaries from the construction sector were the second largest regional share

[2] Income data are from [8, 9] and employment from [1, 2]. Income figures as reported in the above sources are identical to the county income estimates published by the Office of Business Economics, U. S. Department of Commerce, while county employment statistics are prepared in cooperation with the U. S. Bureau of Labor Statistics. Thus, data used in the study should be comparable to the national series.

Table 1. Shift-share analysis of income changes, four rural counties in Alabama, 1960–1969

Sources of Income	1960	1969	Change 1960–69	Components of income change: National growth	Component mix	Regional share	Net relative change[1]
	Thousand Dollars						
Personal income	110,286	212,250	101,964	95,508	−3,136	9,599	6,463
Fast growing components	42,716	99,445	56,729	36,994	13,619	6,120	19,739
Other labor income	3,523	9,326	5,803	3,051	2,237	514	2,751
State and local government	4,010	8,449	4,439	3,473	1,909	−942	967
Services	2,493	6,372	3,879	2,159	930	790	1,720
Transfer payments	13,138	29,925	16,787	11,378	4,493	920	5,413
Federal government	6,007	10,336	4,329	5,202	2,036	−2,907	−871
Property income	10,690	24,217	13,527	9,258	1,732	2,534	4,266
Finance, insurance, and real estate	958	3,814	2,856	830	102	1,925	2,027
Contract construction	1,897	7,006	5,109	1,643	180	3,286	3,466
Slow growing components	70,084	121,399	51,315	60,692	−14,349	4,975	−9,374
Manufacturing	39,057	74,954	35,897	33,823	−2,500	4,570	2,070
Wholesale and retail trade	7,307	13,934	6,627	6,328	−1,352	1,651	299
Transportation and public utilities	2,141	6,241	4,100	1,854	−475	2,721	2,246
Nonfarm proprietor income	11,790	14,768	2,978	10,210	−4,610	−2,617	−7,227
Mining	0	940	940	—	—	940	940
Farm proprietor income	8,421	9,370	949	7,292	−4,244	−2,097	−6,341
Agriculture	1,368	1,192	−176	1,185	−1,168	−193	−1,361
Less: Personal contributions for social insurance	2,514	8,594	6,080	2,177	2,406	1,496	3,902

[1] Net relative change refers to the combined component mix and regional share effects. The combined effect is used in this manner throughout this paper. Net relative change plus national growth may not equal total change due to rounding.

effect. Negative effects occurred in federal government wage and salary disbursements, nonfarm proprietor income, and farm proprietor income.

Similar interpretation may be made for the employment changes in Table 2.

Evaluation of the Technique

How valid is the shift-share approach? Recently, the technique has undergone criticism on several grounds. Houston [15] contends that it is devoid of behavioral content, that

Table 2. Shift-share analysis of employment changes, four rural counties in Alabama, 1960–1969

Sources of Employment	1960	1969	Change 1960–1969	Components of employment change: National growth	Industrial mix	Regional share	Net relative growth
	Number						
Total Employment	26,330	32,250	5,920	6,266	−2,054	1,713	−341
Fast growing components	6,080	9,220	3,140	1,447	979	714	1,693
State and local government	1,405	2,920	1,515	334	442	738	1,180
Services	1,335	2,020	685	318	363	4	367
Finance, insurance, and real estate	285	560	275	68	27	180	207
Wholesale and retail trade	3,055	3,720	665	727	147	−208	−61
Slow growing components	20,250	23,030	2,780	4,819	−3,033	999	−2,034
Federal government	1,020	1,180	160	243	−23	−59	−82
Manufacturing	13,850	16,960	3,110	3,296	−512	332	−180
Contract construction	635	1,340	705	151	−30	584	554
Transportation and public utilities	605	650	45	144	−79	−20	−99
Mining	0	100	100	0	0	100	100
Agriculture	4,140	2,800	−1,340	985	−2,389	62	−2,327

only the regional share or competitive component utilizes regional information, and that the components of the analysis are not independent of the level of aggregation. Brown [7] maintains that shift-share analysis is not a useful framework for regional projections. He further contends that the differences between national and regional growth rates—the competitive component—are not stable.

Ashby [4, 5], in rebuttal, asserts that shift-share provides a rational and orderly method for sorting out factors which relate to differences in the rate of growth among regions. Bretzfelder [6] appears to be of the same opinion as Ashby. Hale [14] suggests that shift-share analysis, where attention has been given to the dating of economic variables, provides information that is useful in describing regional economic activity. Thus, most arguments in favor of the technique point out that it should be used merely as a *descriptive* tool and should not be used to explain the ultimate causes for changes in key growth variables. It does provide a quantitative means of describing changes in these variables. Most attacks on the technique appear to be aimed at its use as an analytical tool rather than a descriptive one.

In summary, shift-share analysis permits an orderly assessment of the industrial changes occurring in an area. It appears to offer a comprehensive and direct tool for relating regional or, in this case, county growth to national growth in terms of income and employment variables. It could be logically extended to compare individual county growth rates with those of the state or region. Depending upon the level of aggregation of the data, as much detail as is desired may be obtained. Nevertheless, for comparison, more needs to be accomplished toward refinement in the selection of geographical, industrial, and temporal bases.

References

[1] Alabama Department of Industrial Relations, "Civilian Work Force Estimates, By County, 1960," *Ala. Labor Market*, March 1969.

[2] ———, "Basic Labor Market Information, By County, 1969," *Ala. Labor Market*, March 1970.

[3] ASHBY, LOWELL D., "Growth Patterns in Employment by County, 1940–1950 and 1950–1960. A New Set of Publications," *Survey of Current Business* 46:9–13, Feb. 1966.

[4] ———, "The Geographic Redistribution of Employment: An Examination of the Elements of Change," *Survey of Current Business* 44:13–20, Oct. 1964.

[5] ———, "The Shift and Share Analysis: A Reply," *Southern Econ. J.* 34:423–425, Jan. 1968.

[6] BRETZFELDER, ROBERT B., "Geographic Trends in Personal Income in the 1960's," *Survey of Current Business* 50:14–44, Aug. 1970.

[7] BROWN, H. JAMES, "Shift and Share Projections of Regional Economic Growth: An Empirical Test," *J. Reg. Sci.* 9:1–18, April 1969.

[8] Bureau of Business Research, School of Commerce and Business Administration, University of Alabama, "Estimated Personal Income in Alabama Counties, Major Types, 1960," (Table), *Ala. Bus.*, Vol. 33, supplemental pages, May 15, 1963.

[9] Center for Business and Economic Research, Graduate School of Business, University of Alabama, "Estimated Personal Income in Alabama Counties, Major Types, 1969," (Table), *Ala. Bus.*, Vol. 41, supplemental pages, Feb. 15, 1971.

[10] CURTIS, WAYNE, *An Analysis of Income and Employment Changes in Four Rural Counties in Alabama, 1960–1969*, Ala. Agr. Exp. Sta. Bull. 417, June 1971.

[11] DUNN, EDGAR S., JR., *Recent Southern Economic Development As Revealed by the Changing Structure of Employment*, Gainesville, University of Florida Press, 1962.

[12] ESTLE, EDWIN F., "Manufacturing Employment Changes in New England—1947–1967," *New Eng. Bus. Rev.*, 8–11, Oct. 1967.

[13] Federal Reserve Bank of Cleveland, "Employment Performances of Cleveland, Pittsburgh, and Cincinnati, 1950–1966. I. Comparison with the United States," *Econ. Rev.*, 3–20, Nov. 1967.

[14] HALE, CARL W., "Shift-Share Analysis As A Descriptive Tool in Regional Analysis," *Miss. Valley J. Bus. & Econ.* 6:65–74, Spring 1971.

[15] HOUSTON, DAVID B., "The Shift and Share Analysis of Regional Growth: A Critique," *Southern Econ. J.* 33: 577–581, April 1967.

A Total Marketing System for U.S. Dairy Cooperatives

EMERSON BABB AND ARLO J. MINDEN

Three models were developed as management planning tools to test various policies employed by dairy cooperatives to implement a centralized production and marketing program. Effects of various pooling plans on distribution of returns to producers and on regional milk production are demonstrated.

CONSOLIDATION and merger of dairy cooperatives to form large-scale organizations are recent developments. These large-scale organizations make possible centralized planning and decision making of programs related to the direction of milk production and marketing over a wide area. Many alternative policies might be pursued in attempting to implement a centralized production and marketing program. The research reported here is aimed at showing the consequences of various policies which a single centralized cooperative might institute.[1] Consequences examined include producer returns, milk movements and associated transfer cost (transportation, inspection, plant handling, and surplus diversion costs), and milk production and consumption. Policy variables include different price structures (level and geographic pattern), Class I base plans, rate of conversion from B to A milk production, and pooling plans which affect blend prices.

Procedures and Data

Three models were developed and used in this study. The first was a quadratic programming (Q.P.) model used to determine the geographic price structure which would maximize producer returns, given consumer responsiveness to price changes in different markets [1].

The second model, the aggregate model, encompassed all milk production and sales in the study area comprised of the Midwest, excluding Michigan and Ohio, and the Southwest and South, excluding Florida. This model was used to determine the consequences of various price, pooling, and Class I base plan policies as well as the impact of Grade B to A conversion where all milk was assumed to be under the direction of a centralized cooperative. This model projects production and consumption by supply areas and consumption centers and least cost movements of milk to satisfy consumption requirements with associated transfer costs. There were no restrictions on milk movements in this model, and reserve requirements were 15 percent of Class I sales in all markets except Chicago and Minneapolis-St. Paul where they were 25 percent.

The third model, the cooperative model, included production and sales of three major cooperatives in the study area. This model was used to determine consequences of policies aimed at centralizing control of the milk currently marketed by the three cooperatives, Associated Milk Producers, Mid-America Dairymen, Inc., and Dairymen, Inc., which lie in the study area. The model also suggests policy implications to each of the three cooperatives where consolidation was not assumed. Supply areas were defined as divisions or pay areas and/or specific plants or clusters of plants. This model also incorporated certain features of cooperatives' operations such as restrictions or added costs imposed by inspection requirements, costs of transporting milk in excess of requirements to distant manufacturing facilities, Class II milk requirements in consumption centers, milk committed to other than Class I use, and plant charges associated with using stand-by pool plants and certain manufacturing plants as a source of milk.

December 1969 and May 1970 were used as base months for the analysis. Data were obtained from the three cooperatives and from statistics of federal milk marketing orders and state milk control agencies. All policies were analyzed using these base periods and many were examined for these months over a five-year period.

The basic framework of analysis for the aggregate and cooperative models is shown in Figure 1. In the initial year, production of Grade A and B milk and consumption are given (base period). The model directs milk from supply centers to consumption centers to

[1] A detailed report of the study results is available from the authors on request.

EMERSON BABB *and* ARLO MINDEN *are professor and associate professor, respectively, of agricultural economics at Purdue University.*

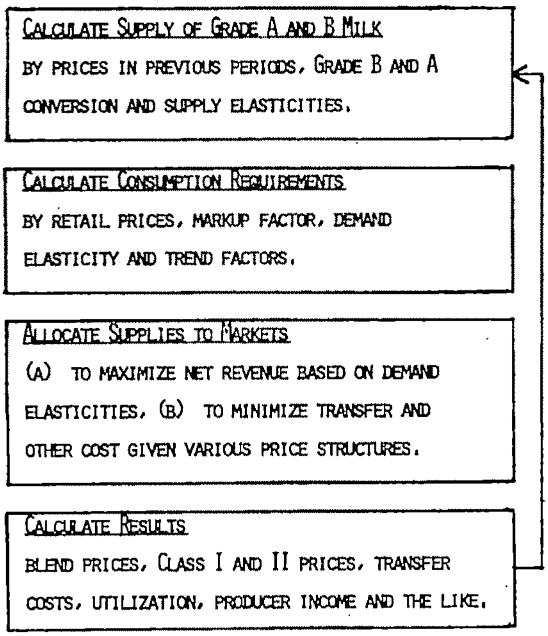

Figure 1

minimize transfer costs. Blend prices for producers in supply areas are then calculated under various pooling and Class I base plans, as well as class prices for milk the next year which were increased 4 percent annually. The model then determines milk production for each supply area given changes in blend price, supply elasticities, and conversion of Grade B to A milk and consumption by markets given class price changes, demand elasticities and trend factors [2]. The model next directs milk as in the first year and continues in this way over the years of interest.

More than 150 policy combinations were tested. Specific policies and situations analyzed are identified in Table 1. The designations in Table 1 are used throughout the presentation of results. Only test results of the cooperative model for the month of May are reported here. This is justified since the directional findings of the aggregate model are similar to those of the cooperative model and the solution prices of the quadratic programming model are used as one of the four price structures to be tested.

Results

Production

Milk production increased under all price structures examined (Table 2). Production increased about 4 percent over the 1970–1975 period in response to higher blend prices and increased an additional 20 percent with the conversion of Grade B to A milk.

Production changed as much as 2.3 percent in some southern markets and as little as 0.5 percent in some northern markets when different pooling plans were imposed. The single Class I price structure raised blend price proportionately more in northern areas, thus stimulating production there. Increased availability from Grade B conversion came mainly from Minnesota, Iowa, and Wisconsin.

Sales

Class I sales declined about 4 percent under the minimum federal order price structure and about 7 percent under the single Class I price over the four years (Table 3). Imposition of the single Class I price or Q. P. price structures affected regional fluid milk sales. Under these price structures, the greatest Class I price increases occurred in northern markets where demand elasticities were generally lower; Class I prices even declined slightly in a few southern

Table 1. Identification of analyses made, aggregate and cooperative models

Price Structure (all class prices increased 4 percent annually)
- I. Minimum federal order price (price plus transport cost)
- II. Single price for all markets ($7.00/cwt. in year 1)
- III. Transportation cost minimization under federal order prices (transport cost only)
- IV. Quadratic programming solution price structure

Pooling Plans
- A. One pool with location adjustments based on .14¢/mile/cwt. from nearest of Chicago or St. Paul.
- B. One pool with location adjustment based on .12¢/mile/cwt.
- C. One pool with location adjustment based on Class I utilization × .14¢/mile.
- D. Four pools corresponding to (1) The Dairymen, Inc. area; (2) Associated Milk Producers, Inc. (AMPI) southern region, plus Mid-American Dairymen, Inc. (Mid-Am.) southern division; (3) Mid-Am. and AMPI central regions; and (4) Mid-Am. northern region and AMPI northern and tri-state regions with location adjustments based on 0.12¢/mile/cwt.
- E. Four pools as above with blend price increased or decreased two cents for each 1 percent pool utilization is above or below the aggregate utilization and with location adjustments based on .12¢/mile/cwt.
- F. Pooling based on local market prices times aggregate utilization.

Conversion of Grade B to Grade A Milk
- A. No conversion
- B. Conversion based on 5 percent per year rate.

Class I—Base Plan
1. No base plan.
2. Production exactly equals base of 75 percent of December 1969 and May 1970 production.
3. Production equals 102 percent of base.
4. Production equals 110 percent of base

markets. Thus, fluid milk sales fall in northern markets at the time of the change in price structure. Class I sales decline less in northern markets, however, since prices are increased on an annual basis.

Class I utilization declined 4 to 5 percent due to higher production and lower Class I sales during the four-year period (Table 2). Grade B to A conversion caused an additional 6 percent decline in utilization.

Class II sales increased about 20 percent under the federal order minimum price structure and about 30 percent under the single Class I price (Table 3). Grade B to A conversion resulted in an additional 30 percent increase in Class II sales, but this represented a change in outlet rather than "new" surpluses.

The largest Class II sales increases were in the northern markets where considerable Grade B milk was converted. In southern markets where surplus handling facilities are limited, a projected 2–3 percent increase in surpluses arising from higher production and lower fluid milk sales must be moved to more distant fluid or manufacturing plants.

Blend prices

Blend prices increased about $1.00 per cwt. under all price structures during the four-year period because of higher Class I prices, even though Grade B to A conversion depressed prices about 20 cents (Table 2). The Q. P. blend prices were about 70 cents above projected minimum federal order blends, while the single Class I price blends were about 30 cents higher.

Table 2. Summary of production and blend prices for six-year analyses, cooperative model, month of May

Price Structure, Pooling Plan, Conversion*	1970	1971	1972	1973	1974	1975
May Production (million pounds)						
II-A-B	1681	1769	1844	1920	1996	2072
II-D-B	1681	1766	1842	1917	1993	2069
II-E-B	1681	1771	1847	1923	1997	2073
III-D-B	1681	1748	1826	1901	1978	2055
III-E-B	1681	1753	1831	1906	1983	2059
May Utilization (percent)						
II-A-B	57	53	51	48	46	—
II-D-B	57	54	51	48	46	—
II-E-B	57	53	51	48	46	—
III-D-B	58	56	53	50	48	—
III-E-B	58	55	53	50	48	—
May Blend Price (dollars)						
II-A-B	5.95	6.14	6.34	6.54	6.75	—
II-D-B	5.95	6.14	6.34	6.54	6.75	—
II-E-B	5.95	6.13	6.33	6.54	6.74	—
III-D-B	5.68	5.89	6.09	6.29	6.50	—
III-E-B	5.68	5.89	6.08	6.29	6.50	—

* Roman numeral stands for price structure, first letter for pooling plan, and second letter for conversion of Grade B milk (see Table 1).

Table 3. Class I and II sales under various price structures

	1970	1971	1972	1973	1974
May Class I Sales (million pounds)					
I*	981	972	961	951	942
II	956	946	936	926	917
III	981	972	961	951	942
IV	898	886	—	—	—
	1970	1971	1972	1973	1974
May Class II Sales (million pounds)					
II-A-A*	720	750	—	—	—
II-A-B	—	820	900	990	1080
III-D-A	700	720	—	—	—
III-D-B	—	780	870	950	1040
IV-A-A	780	850	—	—	—
IV-A-B	—	910	—	—	—

* Roman numeral stands for price structure, first letter for pooling plan, and second letter for conversion of Grade B to Grade A milk (see Table 1).

One pooling plan (Plan A) produced blend price patterns nearly fitting the current geographic structure, but some significant blend price differences were observed which may provide barriers to producers' acceptance of the total market concept. Extreme differences in blend prices of 50 to 60 cents under different pooling plans were observed in the northern- and southernmost supply areas. A large part of the membership resides in these areas, so it is clear that a pooling plan acceptable to both groups must be devised.

Blend prices were 30 to 50 cents higher at the end of the 1970–1974 period when Class I base plans were in effect. One method of granting a Class I base to milk converted from Grade B depressed the blend price only 8 cents by the end of four years, compared to the method of no base being granted such milk.

Total value of milk sold increased 20 percent under federal order minimum prices and 27 percent under the single Class I price structure. The addition of Grade B milk increased pool value 10 percent.

Milk movements

The only apparently "odd" movement in any of the analyses was in Albuquerque where milk

in excess of fluid requirements was sent to Oklahoma metropolitan areas to avoid high surplus disposal cost. This occurred because of lower total transportation costs associated with one long haul as opposed to diversion to closer but more costly disposal outlets. Most of the intermarket milk movements were either from country plant to consumption centers (Wisconsin, Minnesota, Missouri) or diversion to avoid high surplus handling charges (Georgia, Texas, and Paducah, Kentucky).

Transfer costs declined over the 1970–1974 period as production increased and consumption decreased, removing the need for some movements. No shipments were called for from areas where added inspection costs prevailed and no surplus milk was transported to distant manufacturing facilities. In reality some shipments may have been necessary on weekends and holidays. Transfer costs increased under base plans where production was curtailed.

Stand-by pool plants

The 15 stand-by pool plants were included in several analyses, but milk in these plants was not called upon to satisfy fluid milk requirements. Given projected production and consumption under all price structures and pooling plans, this would have been the case for the 1970–1974 period. However, this does not mean that milk in the stand-by pool might not be needed in at least some markets during at least part of some months.

If milk in stand-by pool plants had been added to cooperative supplies on a full pooling basis, Class I utilization in December and May would have declined 3 percent and blend prices would have been six to eight cents lower. If stand-by plants were pooled under current federal orders, the 102 million pounds of milk in May would affect blend prices of all producers, not just cooperative members.

Concluding Remarks

The purpose of developing the models was to reveal the short- and long-run consequences of pursuing different policies. They are thus management planning tools. Changes in price structure could significantly enhance producer income, but it is clear that these gains are contingent upon adoption of some type of Class I base plan that will keep production in reasonable balance with consumption, especially with the projected conversion of Grade B to A milk. The effects of various pooling plans on the distribution of returns to producers and on regional milk production are also clearly demonstrated.

The models are also useful planning devices for operational decisions. Reduction in milk movements and transfer costs and better utilization of plant facilities are possible through centralized decision making, and the cooperatives have already moved to capture many of these cost savings. The models point out where surplus disposal facilities would be adequate or inadequate in five years, under various price and pooling policies. The "transportation problem" component of the model is being implemented to direct milk from supply areas and supply plants to consumption points on a daily basis.

The use of computer models for analyzing policy alternatives facing dairy cooperatives was not particularly relevant until the advent of large-scale organizations. Now that they are established, many more applications of the kind reported here can be expected. Improvement in the quality of decision making is an empirical question which time will reveal.

References

[1] Bulletin, G. W. M., "Estimation of Regional Retail Demand Elasticities for Whole Milk, U. S. 1961–1968," unpublished Ph.D. thesis, Purdue University, 1970.

[2] Dobson, W. D., "An Analysis of Alternative Price Structures and Intermarket Competition in Federal Order Markets," unpublished Ph.D. thesis, Purdue University, 1969.

Is There Disinvestment in the Farming Sector?*

ALLEN G. SMITH

The farming sector is not in a period of net capital withdrawal. The accounting system for the farm sector in the national economic accounts indicates a net *disinvestment*, while the USDA Balance Sheet accounts *overstate* investment. This article presents an alternative which uses a cost basis for land.

THE ACCOUNTING system used in the national economic accounts of the Federal Reserve System indicates a net disinvestment for the farm sector amounting to about $3 billion in 1967 [5]. The report by the National Advisory Commission on Food and Fiber [4, p. 234] states (for the period 1960–65), "In effect farmers have withdrawn some capital from agriculture. Farmers have used more than $12 billion of the money generated by depreciation and borrowing for other than working capital." The Balance Sheet of the Farming Sector [8], in contrast, shows that proprietors' equities doubled between January 1, 1949, and 1969. Even though the national economic accounts are flow concepts and the Balance Sheet accounts are stock concepts, an inconsistency still is evident.

Which system of accounts presents the most accurate picture of what is happening in agriculture? Perhaps neither. Penson, Lins, and Irwin [5] have discussed the national economic accounts and their interface with the farm sector. Bhatia [1] critiqued the USDA series on net investment in farm real estate. He identified some weaknesses in the current method of measuring capital expenditures and depreciation on farm real estate. The discussion in both articles, however, centered on maintaining the present accounting system with adaptations.

The objective of this paper is to present an alternative accounting system which permits an increase in capital accumulation through the land inventory by including the additional cost of land purchased in any given year.[1]

Review of Definitions

Some definitions will help to clarify the following discussion. *Investment* may be defined as the creation of assets that produce income [3]; or, alternatively, as the present allocation of money in the expectation of receiving a larger amount of money at some time in the future [2]. Investment is a flow concept and may be measured at the firm level or some aggregate level, such as nationally.

Real estate is defined as land plus buildings and other improvements. *Land* is the physical ground exclusive of capital improvements. A *capital asset* is any asset that yields a flow of services over time [3].

Problems in Measuring Investment in the Farming Sector

At the firm level the change in investment in capital assets can be measured as the total expenditures on these assets minus the capital consumption charged against them. At the national level a problem of aggregation arises. Land is an asset that can be added to the investment of the farm firm, but on an aggregate national level the physical quantity of land remains relatively constant. The national economic accounts assume only minor changes in land inventory over time due to investments in land clearing, irrigation, and other direct land improvements, but include changes in real estate debt in the accounts. Thus, for the most part, the national accounts show little increase in the value and productivity of land. Additions to and capital consumption of buildings are included in capital expenditures accounts.

Real estate constitutes about two-thirds of all assets in the Balance Sheet of the Farming Sector. Since land accounts for about 80 percent of all farm real estate [7], to ignore land in the investment category is to disregard more

* The opinions and statements in this article are the views of the author and do not reflect the policies of the Economic Research Service of the USDA. Helpful comments on an earlier draft of this paper were made by C. B. Baker, Franklin Reiss, Gordon Rodewald, and Kenneth Krause.

[1] The cost basis of real estate is shown in the 1969 Balance Sheet of the Farming Sector [8]. Bruce B. Johnson calculated the cost value of real estate from the results of the 1966 Pesticide and General Farm Survey conducted by the Economic Research Service. The benchmark year was 1966. The other real estate cost values were extrapolated from this benchmark and the land values separated out by the author.

ALLEN G. SMITH *is an agricultural economist with the Economic Research Service, USDA, Washington D.C.*

than one-half of the total capital used in production of farm products.

The second major problem in the farming sector is the interrelationship of the household and the production units of the farm firm. The national economic accounts transfer all net farm income (except retained earnings of farm corporations—a small amount) to the household sector and do not transfer any off-farm income into the farm sector.

Under these circumstances, increased investment is almost impossible. The only internal funds available are from depreciation allowances and in the long run these do not permit increased investment. As land prices increase the total farm real estate debt increases with no compensating increase in value of the land inventory. The net result is "disinvestment" in agriculture, but since more than one-half of the production assets are ignored, this result is not very meaningful.

Land in the Farm Sector Inventory

An alternative "cost" accounting procedure would permit a change in land inventory to the farming sector. In the Balance Sheet accounts, real estate (including land) is inventoried at current market prices. This figure does not show the flow of funds into or out of the farming sector since funds flow only when the real estate changes hands or is used for security to borrow money. If land were included in the accounts on the basis of cost, the land investment figure would indicate the additional amount of funds allocated to land resources in the production of farm products as farms are purchased. For example, a farm purchased in 1950 for $250 per acre is sold at $850 per acre in 1970. No additional funds actually moved into the farming sector between 1950 and 1970. When the farm was sold, the buyer supplied $850, but the additional allocation of funds to the farming sector was only $600 per acre.

Assume, for illustration purposes, this farm had no buildings and no debt on it. The seller of the land removes $850 from the farming sector and the buyer supplies $850 to the sector with a net change of zero. The funds invested in the farming sector appear to be the same as before. Actually, only $250 was invested in the land before the transaction and $850 after the transaction, and the difference represents funds that flowed into the farming sector. In the national economic accounts, no recognition of the change has taken place.

If the acre of land in 1950 was the same productive plant as in 1970, then the idea of no change in investment would be more valid, but a buyer of land does not buy just land but a package of goods. For example, included with the acre of cornland is the capitalized value of income guarantees of the feed grain program, hybrid corn, fertilizer, and other improved production practices. Thus, a buyer purchases more productive cornland along with a higher guaranteed income potential.

The major difference between land and depreciable resources is that land must be paid for out of retained earnings. This is impossible in the national economic accounts because the flow of earnings from the use of the land assets are all assumed to be consumed by the household sector or invested in nonfarm assets. This shortcoming can be corrected by revaluing land in the accounts on the basis of cost at time of purchase. This method of valuing the land inventory (cost basis) is closely comparable to industrial investment accounts.

Net Investment in the Farming Sector

Alternative estimates of aggregate farm investment are shown in Table 1. The change in land inventory on the cost basis was computed from information in the 1966 Pesticide and General Farm Survey conducted by the Economic Research Service. The respondents were asked to give the date of purchase and the price of the land they were operating on the date of the survey. The land value was separated from building values on the basis of information in *Farm Real Estate Market Developments*. The value of the land was then adjusted to a cost basis and the change in the adjusted values between January 1 and December 31 was used as the net change in land inventory.

The data in Table 1 provide a comparative format for three different accounting systems. The Federal Reserve account shows a disinvestment of $2.3 billion for 1967.[2] The implication is that all of net farm income, off-farm and nonfarm income, plus $2.3 billion of appreciated value of land, has been used for consumption purposes or nonfarm investment. The allocation of income for the purchase of land is not recognized under this system. The Balance Sheet (current value) accounts show $8.3 billion increase in investment in the farming sec-

[2] The Federal Reserve accounts do not separate out the farming sector. The account presented here is an adaptation of their accounts to the farming sector.

Table 1. Alternative investment accounts, net investment calculation[1]

Item	1967			1960	1969
	Federal Reserve account	Current value basis	Land cost basis	Land cost basis	Land cost basis
	Billion dollars				
Total	24.5	38.3	38.3	25.8	41.9
Net investment					
Capital expenditures[2]	6.5	6.5	6.1	4.0	6.2
Less capital consumption	5.7	5.7	5.7	4.2	6.7
Net capital expenditures	0.8	0.8	0.4	−0.2	−0.5
Net change in inventory[2]	0.7	0.7	0.5	0.3	0.3
Net investment in financial assets	0.9	0.9	1.0	0.8	0.7
Net change in land inventory	0.0	10.6	4.6	1.1	2.4
Total	2.4	13.0	6.5	2.0	2.9
Less net change in debt	4.7	4.7	4.7	1.4	3.5
Net investment	−2.3	8.3	1.8	0.6	−0.6
Sources of funds					
Net farm income	14.1	14.1	14.1	11.7	16.1
Off-farm income[2]	—	13.8	13.8	8.5	15.6
Capital consumption	5.7	5.7	5.7	4.2	6.7
Change in real estate debt	2.2	2.2	2.2	0.7	1.3
Change in non-real estate debt	2.5	2.5	2.5	0.7	2.2
Total	24.5	38.3	38.3	25.8	41.9
Uses of funds					
Capital expenditures[2]	6.5	6.5	6.5	4.0	6.2
Net change in inventory[2]	0.7	0.7	0.7	0.3	0.3
Net investment in financial assets	0.9	0.9	0.9	0.8	0.7
Net change in land inventory	0.0	10.6	4.6	1.1	2.4
Proprietors' withdrawals	16.4	19.6	25.6	19.6	32.3

[1] The sources of funds, uses of funds, and Federal Reserve accounts are adapted from the format used by Penson, Lins, and Irwin [5].
[2] For 50 states, other data for 48 states.

tor. This value is too high, however, since income has not been allocated for this total amount. Funds are allocated only when the land is sold or money borrowed. Increasing the value of the land on an accounting basis without any actual movement of funds does not measure investment in the farming sector.

On a cost basis, a net investment of $1.8 billion is shown for 1967. The indication is that the farming sector has allocated $1.8 billion of its investment funds in 1967 for the purpose of increasing its capital stock. In an earlier study of consumer expenditures and income of the United States, a sample of the farm population indicated that about 11 percent of the total income (farm and nonfarm) of farm families was used to increase the value of assets and liabilities. About 80 percent of this amount (or 9 percent of the total) was used to increase farm business assets.[3] In 1960, however, the increase in investment in Table 1 was only 3 percent of total income but was 6 percent in 1967.

[3] This survey [6] was limited in scope but does give some indication of expenditures.

Conclusions

The Federal Reserve national economic accounts, as they are currently structured, understate the flow of funds into farm capital. Conversely, the USDA Balance Sheet accounts tend to overstate the flow of funds into farm capital since appreciated land values do not enter the flow of funds until the land is used as security for a loan or is sold.

The farm sector is not in a period of net capital withdrawal. The farm sector is not using all of its net farm income, off-farm income, and a portion of the appreciated land value, through farm real estate loans, for household consumption and nonfarm investment. In 1967, funds invested in capital increased $1.8 billion. Capital expenditures (less land) exceeded capital consumption by $0.4 billion, expenditures on land exceeded the cost to the seller of the land by $4.6 billion, financial assets increased $1.0

billion and inventories $0.5 billion. Debts increased $4.7 billion, resulting in $1.8 billion coming from internal or external funds.

Further research is needed to improve periodic estimates of a cost basis for land. Better data are also needed on the allocation of net farm income and off-farm income between the farm and household sectors.

References

[1] BHATIA, KUL B., "The USDA Series on Net Investment in Farm Real Estate—A Critique," *J. Am. Stat. Assoc.* 66:492–495, Sept. 1971.

[2] BOSTWICK, DON, *Partitioning Financial Returns: An Application to the Growth of Farm Firms*, ERS, USDA, ERS-390, Jan. 1969.

[3] DEWEY, DONALD, *Modern Capital Theory*, New York and London, Columbia University Press, 1965.

[4] *Food and Fiber for the Future*, Report of the National Advisory Commission on Food and Fiber, July 1967.

[5] PENSON, JOHN B., JR., DAVID A. LINS, AND GEORGE D. IRWIN, "Flow-of-Funds Social Accounts for the Farm Sector," *Am. J. Agr. Econ.* 53:1–7, Feb. 1971.

[6] U. S. Department of Agriculture, Agricultural Research Service, *Consumer Expenditures and Income, Rural Farm Population, United States, 1961*, USDA Consumer Expenditure Survey Report No. 35, Aug. 1966.

[7] ———, Economic Research Service, *Farm Real Estate Market Developments*, CD-73, Aug. 1969.

[8] ———, *The Balance Sheet of the Farming Sector, 1969*, Agr. Info. Bull. 340, Jan. 1970.

PROCEEDINGS PAPERS

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PROCESS ANALYSIS AND ECONOMICS OF PRODUCTION

CHAIRMAN: FRED WIEGMANN, LOUISIANA STATE UNIVERSITY

Process Analysis and the Neoclassical Theory of Production

NICHOLAS GEORGESCU-ROEGEN

TO ABUSE a term is to use it without any attempt at explaining its meaning. In this sense, "process" has been abused in all sciences, but in none as much as in social sciences. Most curiously, in economics the greatest abuse has taken place where one would least expect it to happen, namely, in production theory. Neoclassical economists as well as the standard economists of latter days have never paused to describe the process of production in some operational manner so that you and I may know what they meant by the term. In comparison with our classical forefathers—who went to great pains to describe and analyze some processes of production, as Adam Smith, for example, did in his famous illustration of the pin factory—modern economists have found intellectual comfort in pure symbolism, so that they have gradually stopped considering even the traditional classification of the production factors.

Glaring evidence of the modern economist's craving for hollow symbolism is the fact that to this day Philip H. Wicksteed's presentation of the concept of production function constitutes the standard approach to the topic. "*The product being a function of the factors of production we have* $P=f(a, b, c, \cdots)$," Wicksteed [17, p. 4] said, and economists, generally, still define this fundamental concept in the same cavalier fashion.[1] If we have changed anything, we have replaced "product" and "factors of production" by the vapid terms "output" and "inputs," a substitution which only increases the reader's illusion that he is offered a cogent analytical definition. Now everyone can rest satisfied with the simple etymological translation: "input" is what we put in, and "output" is what is put out.

To be sure, symbolism has been the soul of science ever since man began to organize his knowledge about actuality. Yet symbolism, if not supported by an operational interpretation of each symbol (or at least of each primary symbol), silently but unfailingly leads the student away from the most arduous and most important task of any special science, that of bringing the human mind in closer contact with actuality. The neglect of clarifying even partially the concept of production function is all the more puzzling in view of the "practical" nature of the economic science as attested, in particular, by the immense number of works which only compute one gigantic "concrete" production function after another.[2] In any case, the omission is not a matter of purely academic interest only. On the contrary, as I have argued in a series of essays [6, 8, 9, 10, Ch. ix], it falsifies our understanding of the production process, a fact responsible for several important blank spots in neoclassical theory of production. One such blank spot concerns the fundamental difference between productive processes in agriculture (or other strongly seasonal activities) and productive processes in manufacturing. An-

[1] This summary presentation of the concept of production function does not only characterize most textbooks—some widely used, e.g., Stonier and Hague [16, p. 219], Leftwich [11, p. 109], Samuelson [15, pp. 515ff]—but it also appears in the writings of some consecrated pundits of our profession, e.g., Frisch [3, p. 41] and Samuelson [14, p. 57].

NICHOLAS GEORGESCU-ROEGEN *is Distinguished Professor of economics at Vanderbilt University.*

[2] It is not only because of this neglect that the relevance of these production functions must be questioned. The other reason pertains to the current econometric practices which also involve a chasm between the nature of statistical observations and the stochastic axioms of multivariate analysis. For this last point see Georgescu-Roegen [7].

other covers the difference between the economy of the productive processes in primary activities, mining and agriculture, and the productive processes in secondary activities. Still another concerns one of the most important factors of economic development, namely, the economy of capital utilization. In the present paper, I propose to review and expand these points and to present some additional results concerning the analysis of cost of production and of factor allocation.

Contradictions, Omissions, and Surmises

If our theory of production is to be an adequate logical representation of actuality, it is absolutely necessary that before making even one step further we insist on knowing what corresponds in actuality to every symbol—including F—in the popular formula

$$(1) \qquad Q = F(X, Y, \cdots, Z),$$

by which standard economics describes any "static" production process. The symbol F must also be included because "function" by itself is an ambiguous term even in mathematics. However, the point is that in the standard theory not even the other symbols are connected in some definite operational manner with data observable in actuality. A few careful authors do go beyond Wicksteed's hollow definition. But they tell two different stories. Some conceive the production function (1) as a relation between the *quantity* of product Q and the *quantities* of factors $X, Y, \cdots, Z$. Others conceive the production function as a relation between the output ***per unit of time*** q and the inputs ***per unit of time*** $x, y, \cdots, z$, briefly, as a relation between ***rates*** of flow:[3]

$$(2) \qquad q = f(x, y, \cdots, z).$$

A clear symptom of the standard economist's lack of respect for epistemological problems is the fact that no such economist seems to have thought of the possibility that the two viewpoints may not be equivalent. Even authorities use both definitions interchangeably.[4] Having been exposed by a long rote to this equivalence, we have become so firmly convinced of its validity that some of my fellow econometricians, on hearing for the first time its denunciation, immediately protested. As Patinkin admitted subsequently, the novelty so astounded him that he could but be certain that the argument misinterpreted the property of homogeneous functions.[5]

The argument, however, is extremely elementary. By definition we have $Q = tq$, $X = tx$, $Y = ty, \cdots, Z = tz$, for ***any*** interval of time t. If the two definitions are equivalent, (1) and (2) yield straightforwardly

$$(3) \qquad tf(x, y, \cdots, z) \equiv F(tx, ty, \cdots, tz).$$

And from this identity we deduce, first, that

$$(4) \qquad f(x, y, \cdots, z) \equiv F(x, y, \cdots, z),$$

and, second, that this common function is homogeneous of the first degree. The presupposed equivalence between (1) and (2) implies, therefore, that absolutely every production process is indifferent to scale, a position which, I hope, is no longer defended by anybody.[6]

An ad hoc attempt to save the day against the foregoing argument led to the suggestion that the quantities are accumulated variable flows:

$$(5) \qquad \begin{gathered} Q(t) = \int_0^t q(t)dt, \\ X(t) = \int_0^t x(t)dt, \cdots, Z(t) = \int_0^t z(t)dt. \end{gathered}$$

This idea makes matters worse. Instead of (3), we have

$$(6) \qquad f[x(t), y(t), \cdots, z(t)] = \sum x(t) \frac{\partial F}{\partial X},$$

for any $x(t), y(t), \cdots, z(t)$, which requires that the production function be a simple linear expression of the inputs [8, p. 43]

$$(7) \qquad f(x, y, \cdots, z) = ax + by + \cdots + cz.$$

The standard economist's lack of interest in arriving at a clear idea of the process of production is reflected also in his silence on the measurability of the "output" and "inputs" involved in (1) or (2). True, from the confusing arguments concerning the measurability of utility there emerged the idea that cardinal measurability is a bogey. A carpenter, we are told,

[3] See the sample list references given in [9], notes 4 and 5.

[4] Ragnar Frisch [3, p. 43] uses the two definitions on one and the same page.

[5] See "Discussion" in [6, p. 528].

[6] In fairness to Wicksteed, one should note that the modern incongruity cannot be laid at his door; he explicitly (although without any explanation) assumed that all production functions are homogeneous of the first degree [17, p. 33].

may very well lay down his measuring rod once, four times, eight times, $\cdots$ and count "one," "two," "three," $\cdots$. Perhaps this idea prompted recent theorists of production to be content with any form of measurability for the factors and the product. As far as pure symbolism is concerned, such a position can raise no objection. But the situation changes if the production function is to reflect a part of actuality. In actuality, practically everything we buy and sell is cardinally measurable, for otherwise we would not be able to speak of uniform prices, i.e., of prices per unit. Even land and labor, which exist in a broad spectrum of qualities, are sold on the basis of a cardinal measure—acres or hours.[7]

Actually, of all students, economists should be the last to accept the doctrine that only ordinal measure counts. For if this doctrine were true, our most powerful tools of analysis would go overboard. If commodities were not cardinally measurable by one method or another, then the principle of decreasing marginal substitution, of increasing or decreasing returns, for instance, would lose the basis on which they are defined. One could, in that case, cause the isoquants to have practically any shape one pleases [5, p. 234; 8, pp. 38ff].

The fact that ordinal scales allow us a tremendous freedom of manipulation has led some to surmise that in each case the scales of the factors can be chosen so that the production function be homogeneous of the first degree (an idea that aims at denying the existence of optimum plants). Joan Robinson [13, pp. 109, 332ff] was first to argue that such a feat could be achieved if factors are measured in "efficiency" units. While she retracted her error at the first opportunity, others persisted in it.[8] That the surmise is not true as a general proposition may be shown by a simple example. Let $q=xy+y$ be the production function in case the product and the factors are measured in usual units. Let us assume that with the "efficiency" scales $x=h(u)$, $y=k(v)$, the production function $q(u, v)=h(u)k(v)+k(v)$ is homogeneous of the first degree. The supposition entails $h(0)=0$, $k(0)=0$. If we make $u=0$ in the defining identity

$$(8) \quad h(\lambda\mu)k(\lambda v) + k(\lambda u) = \lambda[h(u)k(v) + k(v)],$$

we obtain $k(\lambda v)=\lambda k(v)$. The introduction of this relation in (8) yields $h(\lambda u)=h(u)$, which is absurd.[9]

Finally, there is another thesis that aims at denying the existence of optimum scale of any process. The thesis is that if all pertinent factors are taken into account all natural laws (and hence any process of production as well) are expressed by homogeneous functions of the first degree. As Samuelson [14, p. 84] pointed out, the thesis is operationally idle. It can be proved that it is, in addition, downright incongruous [10, p. 107]. For if in any relation $y=f(x_1, x_2, \cdots, x_n)$, assumed to be the complete expression of a natural law, m factors are left out, the observations of those retained will generally fill a subspace of $n-m$ dimensions. Consequently, the observations of the $n-m$ retained factors could not possibly reveal to us the existence of any law.

Process: An Analytical Tangle

There is, however, some reason why the meaning of "process," a term so frequently used, is hardly clarified in the special scientific literature. Process implies Change, and Change is the most baffling concept in philosophy. Perhaps Change is only illusion—as many philosophers maintain. Perhaps everything is permanently there, just as the paintings of a museum which gradually emerge into our apprehension as we walk from one room to another. Be this as it may, to explain Change is the highest aim of any special science, even though we usually proclaim that science can study only what does not change. This proclamation seems intended to conceal the true difficulty of science in general, which is that our Understanding cannot conceive an action without an agent. The verb "becomes," like all verbs, requires a subject (in grammar as well as in our comprehension). And the rub is that "Jim became tired" is a very unsatisfactory thought. How can we conceive Jim as the *same* person before and after the event of his becoming tired? The fact that there is something to which we refer as "Jim" both before and after that event does not suffice in the least to establish sameness. Witness the

[7] On the issue of cardinality, see Georgescu-Roegen [5].

[8] E.g., McLeod and Hahn [12, pp. 132ff]. The stronger and hence the more inept position that factors can be measured in efficient units even when they differ qualitatively is basic in many econometric works on technological change.

[9] In [8, p. 39 n] I stated without proof that also the assertion by Dorfman [2, p. 82] that one can define the inputs and outputs "in such a way that all production functions are linear" is not true. This refutation is a little more involved because of the additional degree of freedom supplied by the scale of the product. A proof of it is spelled out in a forthcoming paper of mine.

fact that there is an entity to which we refer as "the President of the United States" both before and after the Inauguration. Sameness raises formidable problems of epistemology. Yet, curiously, most of them seem hardly touched by philosophers. For good measure, think of a cosmic event perceived by one observer as a flash, and as a slight wave of warmth by another who travels at a greatly different relative speed. Unsuspected though the fact may be, the issue of sameness is, as we shall see presently, a most crucial one in arriving at an analytical representation of a production process.

One may circumvent all these difficulties by subscribing to the basic tenet of Dialectics, which is that Being is Becoming. However, science cannot be erected on this foundation. For science must distinguish between "object" and "event," that is, between Being and Becoming. It is this distinction that draws the line between Dialectics and Analysis. Analysis offers science the great advantages of precision and easier description of actuality. But these advantages have a price: the endless paradoxes and logical contradictions that emerge from almost every analytical framework to remind us of the dialectical nature of actuality as well as of our thought. Actuality—we must stress the point—is seamless. Hence, violence is done to it as Analysis slices it into discretely distinct pieces in order to facilitate our Understanding.[10]

The upshot is that any analytical science can study only partial processes, i.e., only slices of actuality. Every *analytical* process, therefore, can be but a partial process. To determine such a process, we need an ***analytical boundary***. This boundary must include the ***duration*** of the process and the "geographical" ***frontier***, which separates the process from the rest of actuality at all times. The conclusion is clear: no analytical boundary, no analytical process.

Several points now deserve pointed emphasis. Since actuality is seamless we can, in principle, draw a boundary wherever we please. However, a student is always guided by some purpose, proper to the domain of his inquiry. Second, the analytical boundary is a void, for otherwise we would need boundaries of boundaries of boundaries . . . , and would be engulfed into an infinite regress. Third, what an analytical process does can be described only by listing everything that crosses its frontier and at what time. If we are interested in studying also what happens inside an analytical process, we must divide it into other processes by drawing new boundaries.[11] Lastly, in drafting the list of the elements that cross the frontier, one must bear in mind that, a partial process being an artificial slice of actuality, such a process is inexistent both before the origin of its duration, $t=0$, and after the end of that duration, $t=T$.

Within this framework "input" and "output" acquire an operational as well as analytical definite meaning. However, Analysis must make now another heroic step, which is to assume that the input and output elements, C_k, exist in a finite number of discretely distinct and measurable qualities. On this basis, the analytical coordinates of a process form a point in a functional space,

$$(9)\quad [\overset{T}{\underset{0}{I_1}}(t), \overset{T}{\underset{0}{I_2}}(t), \cdots, \overset{T}{\underset{0}{I_n}}(t); \overset{T}{\underset{0}{O_1}}(t), \cdots, \overset{T}{\underset{0}{O_n}}(t)],$$

where $I_k(t)$ is the cumulative input and $O_k(t)$ the cumulative output of C_k up to time t (inclusive). The same element may appear both as input and as output. Think of a process consisting only of locomotion (which involves no qualitative change) or one in which electrical motors are used to produce electrical motors.

The analytical picture (9) may suit many a special science, but not economics. In economics, commodities play the same fundamental role as that played by cells in biology, by molecules in chemistry, by elementary particles in physics. Commodity fetishism, notwithstanding its loud denunciation by Karl Marx, is the indispensable foundation of economics. Witness the fact that if we reexamine the entire literature on economic production, Marx's included, in the light of the argument of this section, we see that every economist has drawn economic boundaries only in relation to some commodity. An engineer, for example, may draw a boundary between the furnace with melted glass and the rolling machines of a plate glass factory, but not so an economist in the past or at present. For melted glass is not and has never been a commodity. The conclusion is that if any ele-

[10] For a detailed discussion of these issues, see Georgescu-Roegen [10].

[11] A point that illustrates the ways in which Analysis may baffle us: if we push this process to the limit, the whole happening slips through our analytical mesh.

ment *that is not a commodity* is an input or an output of a production process represented by (9), a thorny problem confronts the economist. For, in that case, how can he set up that indispensable tool in any science, namely, the balance between inputs and outputs, which in economics means a value balance? And the fact is that numerous elements of any production process are not commodities proper—tired workers, worn-out tools, and waste are normal outputs, while free goods are normal inputs.

The solution of the impasse lies in the analytical fiction of the static process or, as Marx more properly described it, the process that reproduces itself. Obviously, for a process to be reproducible, some of its elements must remain intact despite the change caused by the process. This is the inevitable consequence of the epistemological position specific to Analysis—that there is both Being and Becoming. It is the common conception that in any production process a number of agents act upon some materials so as to transform them into products. In a static process, the distinction necessarily leads to the division of the analytical coordinates into two categories—the *flow* and the *fund* (not stock!) elements. A flow is an element that either is only "consumed" or only "produced" by the process; it is either only an input or only an output. A fund is both an input and an output; more precisely, it is a factor whose economic efficiency is maintained by the very process in which it participates. The distinction, obviously, breaks down in the case of locomotion. However, locomotion as such presents no interest whatsoever for the economist. Even when locomotion is apparently the case—as it is in an oil pipeline—the economist has all the reasons in the world for treating the oil at the source and the oil at the destination as two different commodities.

The distinction may, however, raise other, more delicate issues which must be handled with what Alfred Marshall so rightly called "delicacy and sensitiveness of touch." For we must not forget the fact that Analysis has to cut some slits in a Whole that has no joints or seams. Ricardian land provides the clearest illustration of the concept of fund, but a machine that is continuously maintained and repaired also fits the definition. Accordingly, a machine coming out of a process is a fund even though it may have no part whatsoever in common with the "same" machine that went into the process at some time in the past. Still more important is another point, which hardly needs any elaboration: the clover seed is a flow in producing clover fodder, but a fund in producing clover seed.

A host of economists have assailed the notion of reproducible (static) process on the ground that it is a far remove from reality. But this objection is as unfounded as that against the fiction of uniform motion. What do most factories do other than reproduce today the process of yesterday? The main difficulty of the notion of reproducible process is of an analytical nature. First, in order to maintain the efficiency of a machine intact, we need other machines. Machines and tools to maintain other machines and tools lead to a regress which may stop only if the reproducible process includes practically every production process in the world. But even this difficulty may be circumvented by introducing the necessary services among inputs. One cannot, however, dispose as easily the fact that workers, other than the self-sufficient farmers, are not maintained within the production process. This analytical blemish, however, does not deprive the notion of reproducible process of its usefulness.[13] Yet the notion carries with it some danger. Its analytical transparency has led and it still leads some economists to ignore the entropic nature of the economic process (which continuously and irrevocably degrades man's environmental dowry) and, as a result, to maintain that the solution to mankind's economic problem lies in the stationary state. The truth, sad though it is, is that this problem is the heart of the evolution of the human species and will end only with the end of that species.

The Elementary Process: A Fundamental Concept

We are now in the position to introduce the basic analytical element of production theory. By an elementary process we shall understand the reproducible process by which one unit (natural or appropriately chosen) of the particular output called product is produced from certain other specified elements. The process by which a table is made by a cabinetmaker from dressed lumber, prepared coating materials, ready-made hardware, is a good illustration in

[13] On the issues mentioned in the last paragraphs, the reader may consult Chapter ix in Georgescu-Roegen [10].

point. But the elementary process is the basis of any production, whether of an automobile, of a pound of steel, or of a transatlantic ship.[13] Given the distinction we can make between flow and fund coordinates, we shall measure the former in ordinary cumulative amounts (flows) and the latter in cumulative services. This idea may seem simple enough, but one point, often neglected, should retain our attention. There is a dimensional difference between flows and services as well as between rates of flow and rates of services. Curiously enough, the rate of service is independent of the time dimension. The rate of service of two workers is just two workers; only their service may be one hundred or eight man-hours depending on its duration. A further point is that "the flow of services" is a license which throws an opaque blanket over an important problem of value. For only the woolen fabric flows into the coat, not so the services of the needle. If you find a needle or a part of it in your new coat, it is only because of a regrettable accident.

In a generic fashion, let us denote the services of Ricardian land by $L(t)$, those of capital proper by $K(t)$, and those of labor by $H(t)$. Similarly, we may denote by $Q(t)$, $R(t)$, $I(t)$, $M(t)$, and $W(t)$ the flows of products, of natural resources, of manufactured articles, of maintenance supplies, and of waste. The complete description of any elementary process is

$$\begin{aligned}[\overset{T}{\underset{0}{Q}}(t), \overset{T}{\underset{0}{R}}(t), \overset{T}{\underset{0}{I}}(t), \overset{T}{\underset{0}{M}}(t), \overset{T}{\underset{0}{W}}(t);& \\ \overset{T}{\underset{0}{L}}(t), \overset{T}{\underset{0}{K}}(t), \overset{T}{\underset{0}{H}}(t)],&\end{aligned} \tag{10}$$

which can also be represented by a series of graphs, one for each element [6, p. 515; 9, p. 3].

This analytical setup brings to light two points of exceptional economic importance. The first concerns the long-standing denial of the value of Ricardian land and natural resources. But there can be no doubt that Ricardian land must be included in a complete description of a productive process. In agriculture, in particular, Ricardian land plays a role wholly analogous to that of a fisherman's net; only, instead of fish, it catches solar energy and its by-products [6, p. 508]. As to the natural resources, we may recall that Karl Marx, of all the economists, recognized that no one can fish from a lake where there are no fish. The omission of these two factors in standard analytical economics as well as in most applied works may also be imputed to the neglect of standard economists for any epistemological clarification of the production function. The consequence has been that the economic process is now viewed as a simple circular affair, as a mechanical analogue, which, like a pendulum, just beats time, but makes no history. The actual economic process, on the contrary, is making its own history, through the continuous tapping of natural resources and the search for a more efficient use of these scarce economic factors.

The second point is that in absolutely any elementary process numerous factors are inevitably idle during parts of the duration. This *technical* idleness is the worst form of economic waste and a great hamper to economic progress. Unfortunately, natural as well as economic factors prevent its complete elimination. The natural factors pertain to season. Some activities, especially farming, have a temporal rhythm over which, for all practical purposes, man has hardly any control. One can begin at any time of the day, of the week, or of the year, an elementary process by which a table or an automobile is produced. But a corn grower must sow corn in the fields within a specific, very short period of the year if he wants to have a crop. The difference is of paramount importance. In the case of manufactured or mined products, we can arrange the elementary processes *in line* in such a manner that each fund shifts to another process as soon as it has finished its task in the previous one. This is the way any factory operates, like an assembly line even though one is not in direct view.[14] There are inexorable physical factors, therefore, that oblige the farmers all over the world (with only a few, but highly instructive exceptions[15]) to grow practically all their products by elementary process *in parallel* (or almost so). In this arrangement, processes begin and end at the same time, with the result that the idleness coefficient of most factors is reduced very little, if at all. Think how long a plow remains idle on a farm compared with the continuous use of a furnace in steel works, for example.

Patinkin, in his argument against the im-

[13] The complications inherent to joint products must be left out at this stage.

[14] The point may be clarified by a diagram as in Georgescu-Roegen [6, p. 517].

[15] The exceptions consist of a few spots around the equator. For their object-lessons, see Georgescu-Roegen [6, pp. 524ff; 10, p. 253].

portance and the relevance of this difference, maintains that in the agriculture of the world viewed as a single process funds are continuously employed. The point is obviously inept: the tractors in the Northern Hemisphere *are* idle during the time those in the Southern Hemisphere are active and both *are* often idle over long stretches of time.[16] On the other hand, the economic importance of the difference between the factory and the farming system is splendidly dramatized by the "chicken war" in Europe, a direct consequence of the transformation of the American chicken farms into "chicken factories." It is not excluded that with time we may find the means for growing pigs or even cattle in a factory system. But in spite of many headline claims progress in that direction does not seem at this time too encouraging. In any case, the old Marxist dream of "factories in the open air" is not going to become a general fact for the farmer, not until man conquers the cosmic power necessary for rearranging the position of the globe on the ecliptic.

For the economic historian, too, the analytical concept developed in this section is highly instructive in that it casts a great deal of light on the intimate connection between the factory system and the intensity of demand, on the one hand, and on the assumed correlation between that system and modern technology. Certainly, if only one table is demanded during the period T, production can be carried on only by elementary processes *in series*, with one process beginning when the previous one ends. Nowadays, this is the case for the production of large ships, of space rockets, for example. At one time, this was the general situation in every artisan shop. If elementary processes must be arranged in series, there is hardly any possibility for reducing the technical idleness. Nor is there any incentive or occasion for some division of labor and even of machinery. A cabinetmaker of old times would not have acted economically if he had divided his tasks between him and another worker or if he had used different saws for different cuts. On the other hand, there is absolutely no reason why a factory system should be incompatible with the technology of the ancient times. Indeed, nothing militates against the idea that in the busy shops work proceeded according to that system even in antiquity. In fact, all these remarks justify the view that with the gradual increase in demand the factory system came to be practiced first in some shops of the eighteenth century and that this evolution spurred the division of labor and induced the fever that caused the Industrial Revolution. The relation of cause to effect may after all be the reverse of that of the accepted doctrine in economic history. And from all one can judge, Adam Smith seems to have had in mind this causal order in his argument relating the division of labor to demand.

The Production Functions

We may next assume—a quite strong assumption, if one stops to think about it—that, for a given product, the representations by (10) of all possible elementary processes form some "surface" in the corresponding functional space. The equation of this surface expressed in terms of the product coordinate is the production function of the elementary processes in point,[17]

$$\overset{T}{\underset{0}{Q}}(t) = \mathfrak{F}[\overset{T}{\underset{0}{R}}(t), \overset{T}{\underset{0}{I}}(t), \overset{T}{\underset{0}{M}}(t), \overset{T}{\underset{0}{W}}(t); \overset{T}{\underset{0}{L}}(t), \overset{T}{\underset{0}{K}}(t), \overset{T}{\underset{0}{H}}(t)]. \tag{11}$$

This "function" is what mathematicians call *functional*. It relates functions to functions, not numbers to numbers as (1) or (2) do.

We may now consider complex processes, beginning with those in which elementary processes are arranged in parallel. One category is illustrated by the growing of corn from seed on several farms in the same geographic area. If the elementary process represents what one farm does, then the corresponding production function is immediately derived from (11):

$$n\overset{T}{\underset{0}{Q}}(t) = \mathfrak{F}[n\overset{T}{\underset{0}{R}}(t), n\overset{T}{\underset{0}{I}}(t), \cdots, n\overset{T}{\underset{0}{H}}(t)]. \tag{12}$$

This is a situation in which the familiar yet misleading tenet "doubling the inputs doubles the output" applies. But there are other cases of processes in parallel to which the tenet does not apply. If (10) is a process by which one bread loaf is baked in a bakery, the baking of a batch of loaves does not require the amplification of all coordinates. The *same* mixing ma-

[16] See "Discussion" in [6, pp. 528ff].

[17] Two remarks are in order here. First, it is not necessary that the production surface should cover the entire factor space. Second, normally $Q(T)=1$ and $Q(t)=0$ for $t\neq T$.

chine, oven, and building can take care of the multiple task.

Difficulties of the kind just mentioned render very tedious the derivation of the factory production function from (11). But this can be achieved in a direct fashion by considering the general representation (10) and observing that in a factory system all coordinates, flows and services, are proportional to the time the factory remains open. Hence, we have for *any* T

$$(13)\quad \overset{T}{\underset{0}{(qt)}} = \mathcal{G}[\overset{T}{\underset{0}{(rt)}}, \overset{T}{\underset{0}{(it)}}, \overset{T}{\underset{0}{(mt)}}, \overset{T}{\underset{0}{(wt)}}; \overset{T}{\underset{0}{(Pt)}}, \overset{T}{\underset{0}{(Ht)}}],$$

where P stands for all funds other than labor. As is easily seen, (13) is a *degenerate* functional which can be reduced in two ways to a point function. The first form is

$$(14)\quad q = \Theta(r, i, m, w; P, H),$$

where every symbol represents either a *rate* of flow or a *rate* of service. The second form is

$$(15)\quad Q = \psi(R, I, M, W; \mathcal{P}, \mathcal{H}; t)$$

where every symbol—except t—is either the *amount* of some flow or the *amount* of some service over the period t:

$$(16)\quad \begin{gathered} R = rt, \quad I = it, \quad M = mt, \quad W = wt; \\ \mathcal{P} = Pt, \quad \mathcal{H} = Ht. \end{gathered}$$

These two forms uncover the root of the confusion created by the two different interpretations (1) and (2) and exposed in the second section, above. It is seen that if the production function refers to a factory process (or to a process consisting of identical factories in parallel), all variables must be *rates of flows or of services*, as in (14). If one insists on describing the factory process in terms of *quantities of flows and services*, the corresponding production must include also the *duration* over which these quantities are accumulated, as (15) shows. Furthermore, we also find that there is some homogeneity of the first degree here, namely, of ψ. It is this form that lends another justification to the tenet mentioned earlier, "doubling the factors doubles the output," provided we specify that the doubling includes the time of production t as well. We also obtain a relation analogous to (3). Only, its correct form is

$$(17)\quad \begin{aligned} &t\Theta(r, i, m, w; P, H) \\ &\qquad = \psi(R, I, M, W; \mathcal{P}, \mathcal{H}; t), \end{aligned}$$

which yields

$$(18)\quad \Theta = [\psi]_{t=1}.$$

The existence of two distinct forms by which a factory process may be represented reflects a normal duality, even though we may not be fully conscious of it. Form (14) describes only what the process is capable of doing and what it needs for being carried on. It is the same way in which we describe an electric bulb by "100 watts, 110 volts." By contrast, (15) tells us what the factory process has done, is doing, or will do during any period t of full activity. The point that in order to describe what a factory actually does we have to refer either to ψ, which includes the time of production t, or to multiply Θ by this factor vindicates Marx's insistence on the importance of the time of production and of the working day for the theory of value. By comparison, we can see how far removed from the basic economic facts standard theory of production is because of the superficial treatment of such a fundamental concept as the production process. In the standard theory of production there is no room for the time of production or for the working day. The result is that planners everywhere seem to ignore completely one of the most effective and readily available levers of economic development—which is the minimizing of plant idleness. Witness the fact that even in the least developed countries plants lie idle the greatest part of the time either because of an anachronic regimen of a 40-hour week or (and) because they are used only by one shift.

The Components of the Factory Production Function

If we try now to project in greater detail the production function (14) against actuality, we immediately see that any such production function is limitational, that is, the nonwasteful combinations of factors satisfy not one but several relations.[18] It is unquestionable that what a factory can do is what its physical plant is capable of doing. Indeed, a qualified engineer can determine the value of q by merely study-

[18] For an introduction to the problem of limitationality and its impact on marginal pricing, see Georgescu-Roegen [4].

ing the blueprints of the factory. This means that the production capacity of a plant q^* is determined only by L and K,

$$q^* = G^*(L, K), \tag{19}$$

and that the same is true of the labor power H^* necessary for utilizing that capacity,

$$H^* = H^*(L, K). \tag{20}$$

A factory, however, may operate below its capacity, in which case what it can do depends also on the labor power $H \leq H^*$ actually employed. A more general relation must therefore replace (19):

$$q = G(L, K, H) \leq q^*. \tag{21}$$

To express what a factory does, we need an additional coordinate, namely, the proportion of the day during which the factory works or, in other words, the working time of the factory. This coordinate is, of course, closely associated with the worker's working day. If we denote it by τ, $0 \leq \tau \leq 1$, and if we assume that H does not vary during τ—which is a reasonable assumption—the amount of *daily* production is given by[19]

$$Q = \tau G(L, K, H). \tag{22}$$

The complete analytical picture of a factory process involves several other categories of factors. The element that comes first to mind represents the inventories, nonspeculative, to be sure. Lacking some detailed inquiries into the matter, we can only surmise that the level of the technical inventories is determined by the size of the other funds considered so far:

$$S = S(L, K, H). \tag{23}$$

The next element is a fund of a peculiar nature. It consists of what we generally call "goods in process." The term is certainly misleading, for half-tanned hides and melted glass, for instance, can hardly constitute goods in the proper sense of the term. The surprising point is that in spite of all our heroic assumptions, it is just not possible to arrive at a picture of a static factory process that involves only commodities proper (besides free goods and waste). But the most peculiar thing about this fund is that in effect it depicts a Becoming, namely, the Becoming represented by all transformation stages through which the product is created from certain material inputs. For this reason we may refer to it as the *process-fund* of a factory. With the same caveat as for the inventory fund, we may assume that the process-fund is determined by

$$\Gamma = \Gamma(L, K, H). \tag{24}$$

There remain the flow coordinates. It stands to reason that for the maintenance flow we have

$$m = m(K, H), \qquad m = w_1, \tag{25}$$

where w_1 is the flow rate of waste correlated to the ingredients and parts of which m consists. The last equality merely expresses the well-known principle of conservation of matter-energy: no process whatsoever can yield an excess or a deficit in these terms. Next, there are the input flows of natural resources and manufactured goods that are transformed by the agents into the output flows of product and correlated waste. Since this transformation, too, must obey the principle of conservation of matter-energy, all these last flows must be related by a homogeneous function of the first order, $qt = g(rt, it, w_2t)$, which yields

$$q = g(r, i, w_2). \tag{26}$$

Finally, we must take into account the fact that what differentiates one factory process from another is the size of the waste flow, i.e., the amounts of the input flows that go to waste. But the size of the waste flow is determined by the structure of the physical plant as well as by the size and the kind of manpower employed. This means that

$$w_2 = w_2(L, K, H), \tag{27}$$

so that (26) must be replaced by

$$q = g[r, i, w_2(L, K, H)]. \tag{28}$$

It is thus seen that the factory production function (14) actually consists of seven main components—relations (21), (23)–(25), and (27)–(28)—and one auxiliary relation, (20). The purely economic coordinate, τ, determines then the daily production Q, the daily maintenance flow $M = \tau m$, and the proper daily flows $R = \tau r$, $I = \tau i$.

Nothing need be added to convince ourselves that this analytical picture of a factory process is a far cry from the crude, colorless formula to which standard economics reduces the descrip-

[19] If we wish to get closer to the real facts in applied endeavors, we must replace τ by a function of the worker's working day and of the number of shifts.

tion of the same process. Some aspects, however, deserve to be emphasized. First, in contrast with the standard formula, the new picture provides a clear analytical basis to some elements that are ignored by that formula. The elements are the working time τ, the production capacity q^*, and the employment H^* for this capacity. As a result, we can now supply specific definitions for several notions that are used but only loosely defined by standard economics. The ratio q/q^* measures the capacity utilization at *a point in time*, while τ measures the capacity utilization *over time*. The overall capacity utilization is measured by the product $\tau q/q^* = Q/Q^*$, where Q^* is the maximum daily production (obtainable for $\tau = 1$). We can also define in a specific way the frequently used notion of labor-capital ratio. If this coordinate is to reflect the organic composition of capital, it must necessarily refer not to the labor power actually employed (which often may be nill) but to the labor power called for by the existing capital. Hence, the labor-capital ratio must be expressed by H^*/K.

In all probability, the fact that τ, q^*, H^* are not parts of the standard analytical framework (which means the standard production function) is responsible for the absence of the corresponding data from current statistical information. The closest element revealed is the number of man-hours supplied during the year or, what comes to almost the same thing, the total wage bill for each industry. What we generally know, therefore, is only $\sum \tau_i H_i$ over the year. Such data have clearly no connection with H^*. They do not even provide some indirect index of the average employment during the year. Certainly, 1600 man-hours may be the result of 400 men each working four hours as well as 200 men each working eight hours.[20] The results of those applied works in which the capital intensity is measured by the ratio between the total wage bill and the value of fixed capital must, therefore, be viewed with great reservations.

The new analytical representation of a factory process enables us to see clearly through the arguments repeatedly advanced in support of the thesis that there are no optimum units, that doubling the inputs doubles the output. As already mentioned, the thesis is confirmed if the doubling is achieved by doubling the time during which the factory works—a point clearly expressed by (22). The homogeneity of the first degree of the function (26) also bears out the thesis provided that we formulate it correctly: if all inputs *and the waste output* are doubled, then the product output must necessarily double. However, the issue of the existence of optimum units does not hinge upon these two almost tautological aspects. Instead, it hinges upon whether doubling the funds, L, K, H in (21) doubles the potential flow rate q. That numerous defenders of the position that scale does not matter in production have ignored the last point may again be due to the fact that the standard production function makes no distinction between flow and fund elements.

Analysis of Cost and Allocation in a Factory System

Much of the standard picture found in every textbook which aims at showing how cost is derived from the production function and how the optimum allocation of liquid capital is achieved on the same basis must now be changed. But before proceeding, I should stress the fact that, in contrast with the complete silence of the standard theory on this restriction, the analysis presented here applies only to the factory. This case, we should note, is the simplest of all. Other types of processes present difficulties which must be left for another occasion.

The total cost T of a daily output Q always consists of two parts: τT_V, the cost that varies proportionately with τ, and T_F, the cost that is independent of τ. (The distinction is analogous but not identical to the standard distinction between variable and fixed cost.) We thus have the identities

$$\begin{aligned} & T = \tau T_V + T_F, \\ (29) \quad & T_V = \sum H p^H + \sum r p^r + \sum i p^i + \sum m p^m, \\ & T_H = \sum L p^L + \sum K p^K + \sum S p^S + \Gamma p^\Gamma, \end{aligned}$$

where the p are prices.

If the management can vary only τ, then the cost of producing a daily output Q, Q varying from $Q=0$ to $Q=q\times 1$, is $T = T_F + (Q/q)T_V$. In this situation, the optimum τ is determined by

[20] This is the elementary reason why t must appear explicitly in (14). The point bears also upon the fact that the static Leontief system is generally described in terms of total flows and the total "flow of labor services," with the result that one can never know the actual scale of operation. For this last point, see Georgescu-Roegen [10, pp. 270ff].

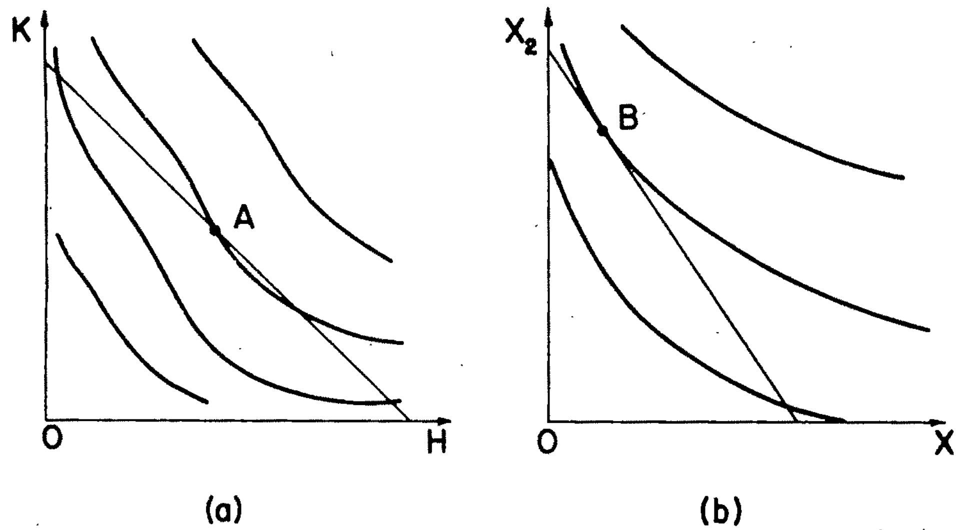

Figure 1

the maximization of profit $R-T$, where $R(Q)$ is the daily total receipts for the offer Q. If $R=pQ$, then the optimum is either $\tau=0$ or $\tau=1$ according to whether $p<$ or $>T_V/q$ and $0\leq\tau\leq 1$ if $p=T_V/q$. If R has the usual parabolic shape, then optimum τ is given by $dR/dQ=T_V/q$.

If, on the other hand, τ is constant and all other elements may vary, then the total cost function must be determined in relation to the usual optimality criterion—the greatest daily output Q for every given total cost T. However, the assumption that τ does not vary is inept, even in the situations in which the worker's working day is limited by law. And since the analysis developed from this assumption is as complicated as the general case, to avoid duplication we may pass directly to the general case in which both τ and all production factors are free to vary—a problem that the standard theory of production could not, per force, even entertain. The main relevant results reached in this direction can be safely brought home by a simplified, albeit unrealistic, structure that leaves out the Ricardian land, the inventories, and the process-fund as well as the maintenance flow. If we also use a uniform notation for all remaining input flows, the production function is reduced to only two components,

$$(30)\quad Q=\tau G(H,K),\quad Q=\tau g[x, w_2(H,K)].$$

In the still more simplified structure in which there are only one kind of labor, one kind of capital, and two kinds of input flows, these relations may be represented graphically by two families of isoquants. These isoquants remain the same as τ varies; only the corresponding product values increase in the same proportion with τ. Figure 1a shows the isoquants of G, Figure 1b those of g.[21] We must, however, make a special note of the fact that, in general, the last map changes as the fund structure (H, K) changes. The graphical representation will enable us to pinpoint some of the results to which we now turn.

The optimalization problem in this case may be stated as follows: to find the maximum of $Q=\tau g$ for a given

$$(31)\quad T=\tau\left(\sum_a p_a{}^H H_a+\sum_c p_c{}^x x_c\right)+\sum_b p_b{}^K K_b,$$

and the additional constraint

$$(32)\qquad G(H,K)=g[x, w_2(H,K)].$$

In (31), $p_a{}^H$, $p_b{}^K$ are the prices of the services of various kinds of labor and capital *per day*, and $p_c{}^x$ are the prices *per customary unit of measurement* of the various input factors. The necessary condition for the maximum τg is $d(\tau g)=0$, to which we must add the constraints $dT=0$, $dG=dg$. Because of $d(\tau g)=0$ and of (32), the last relation may be replaced by the simpler one, $d(\tau G)=0$. We thus must have:

[21] The reason why the isoquants in Figure 1a are not necessarily convex toward the origin—as the standard theory assumes them to be—is revealed below.

$$dT = \tau\left(\sum_a p_a{}^H dH_a + \sum_c p_c{}^x dx_c\right) + \sum_b p_b{}^K K_b + T_Y d\tau,$$

$$(33)\quad d(\tau G) = \tau\left(\sum_a G_a{}^H dH_a + \sum_b G_b{}^K dK_b\right) + G d\tau$$

$$d(\tau g) = \tau\left(\sum_a g_a{}^H dH_a + \sum_b g_b{}^K dK_b + \sum_c g_c{}^x dx_c\right) + g d\tau,$$

where the partial derivatives are denoted according to the pattern $G_a{}^H = \partial G/\partial H_a$.

To avoid the complications associated with a corner solution (which are irrelevant for the immediate argument), we shall assume that these linear equations may be simultaneously satisfied for differential elements that otherwise vary freely. This means that the corresponding linear forms are not independent. Hence:

$$(34)\quad \begin{aligned} &p_a{}^H - \lambda G_a{}^H - \mu g_a{}^H = 0, \\ &p_b{}^K - \tau\lambda G_b{}^K - \tau\mu g_b{}^K = 0, \\ &p_c{}^x - \mu g_c{}^x = 0, \\ &T_Y - \lambda G - \mu g = 0. \end{aligned}$$

If τ is given, then the last relation must be eliminated.

In either case, from (34) we obtain

$$(35)\quad p_c{}^x / g_c{}^x = \mu,$$

$$(36)\quad \frac{p_a{}^H - \mu g_a{}^H}{G_a{}^H} = \frac{p_b{}^K - \tau\mu g_b{}^K}{\tau G_b{}^K} = \lambda,$$

for all a, b, and c.

Relations (35) show that for the optimal factor combination the marginal rates of substitution of the flow factors are equal to the price ratios. In Figure 1b, the corresponding budget line is, therefore, tangent to the isoquant at the optimal combination $B(x_1, x_2)$. This result does not differ from the standard theory of factor allocation. For comparison, we may recall that, if (1) is the production function and if $T = \sum p_i X_i$ is the total cost, instead of (33) we have

$$(37)\quad dT = \sum p_i dX_i = 0,\ dF = \sum F_i dX_i = 0,$$

where $F_i = \partial F/\partial X_i$. As above, we obtain

$$(38)\quad p_i - \mu F_i = 0,$$

and further

$$(39)\quad \frac{p_i}{F_i} = \mu = \frac{dT}{dQ} = \frac{T}{F^*},$$

where

$$(40)\quad F^* = \sum X_i F_i \cdot$$

But (36) offers the surprise that the ratios of the fund prices are no longer equal to the corresponding marginal rates of substitution derived from either relation (30). The result is that in Figure 1a the budget line of the fund factors, $\tau p^H H + p^K K = T_0$, is not necessarily tangent to the isoquant of the optimal combination $A(H, K)$. From (36), it is seen that the tangency obtains if and only if

$$(41)\quad \frac{g_a{}^H}{G_a{}^H} = \frac{g_b{}^K}{G_b{}^K}$$

for all a and b. In view of the definition of g by (30), the last relations become

$$(42)\quad \left(\frac{\partial w_2}{\partial H_a}\right) \Big/ G_a{}^H = \left(\frac{\partial w_2}{\partial K_b}\right) \Big/ G_b{}^K.$$

Recalling a main theorem of the Jacobian, we easily recognize that (42) represents the necessary and sufficient conditions for w_2 to be a function of G, in effect, of q. Hence, the second equation (30) may be solved for q and replaced by

$$(43)\quad q = h(x).$$

If this is the case, the isoquant map of the flow factors no longer shifts with the fund structure. The isoquants of the two families are now paired, $G = q^0$ is paired with $g = q^0$. Without some knowledge of the actual structures of factory production functions, it is hard to judge whether this case is realistic in any way. A reasonable guess would be that it is not. If waste depends only on the size of the product flow, it should be the same regardless of the extent to which capital is substituted for labor. Be this as it may, even if (43) is true, (36) shows that the optimal factory depends not only on prices but *also on* τ (if τ is fixed). And in either case, the marginal rates of substitution between funds are not equal to the price ratios unless $\tau = 1$.

The point that marginal productivity makes

no sense in the case of limitational factors is elementary. We must therefore be careful not to equate any of the partial derivatives contained in the foregoing calculations with the marginal productivity of the corresponding factor. An increase in the input flow rate x, for example, will not cause any increase in the product flow unless the fund factors are appropriately adjusted to handle that increase. However, the partial derivatives still enter into the basic formulas. These formulas may be derived either by blind calculus, as we have done above, or directly by determining the increments that match each other in the optimum manner [4]. For example, any increase dx must be accompanied by an adjustment of at least one fund factor, which means that the corresponding increments must satisfy the relations

$$(44) \quad g_a^H dH_a + g_c^x dx_c = dq, \quad G_a^H dH_a = dq.$$

Since the corresponding additional cost is $dT = \tau(p_c^x dx_c + p_a^H dH_a)$, (44) yields

$$(45) \qquad \frac{dT}{dQ} = \frac{p_c^x}{g_c^x}\left(1 - \frac{g_a^H}{G_a^H}\right) + \frac{p_a^H}{G_a^H}.$$

If the adjustment is made by a change in K, the additional cost is $dT = \tau p_c^x dx_c + p_b^K dK_b$, and instead of (45) we have

$$(46) \qquad \frac{dT}{dQ} = \frac{p_x^c}{g_c^x}\left(1 - \frac{g_b^K}{G_b^K}\right) + \frac{p_b^K}{\tau G_b^K}.$$

Now, since dT/dQ must be the same for any possible combination of increments, (45) and (46) yield (35) and (36). In fact, (45) and (46) are the correlative relations of $dT/dQ = p_i/F_i$ in (39). Finally, because of (34) we have straightforwardly $dT = \lambda d(\tau G) + \mu d(\tau g)$ or

$$(47) \qquad \frac{dT}{dQ} = \lambda + \mu,$$

a relation that mirrors $dT/dQ = \lambda$ of (39).

In order that the solutions supplied by (34) should correspond to a maximum of $Q = \tau g$, we must have $d^2(\tau g) < 0$ subject to the first two constraints of (33). The simple structure of Figure 1 will suffice to pinpoint the relevant results of this new problem. According to a classic theorem of quadratic forms, the condition that $d^2(\tau g) < 0$ subject to $dT = 0$, $d(\tau G) = 0$, is equivalent to a condition pertaining to the signs of the progressive sequence of the principal minors of the matrix[22]

$$(48) \quad \begin{bmatrix} 0 & 0 & 0 & 0 & \tau G^H & \tau G^K & G \\ 0 & 0 & \tau p_1 & \tau p_2 & \tau p^H & p^K & T_V \\ 0 & \tau p_1 & \tau g^{11} & \tau g^{12} & \tau g^{1H} & \tau g^{1K} & g^1 \\ 0 & \tau p_2 & \tau g^{21} & \tau g^{22} & \tau g^{2H} & \tau g^{2K} & g^2 \\ \tau G^H & \tau p^H & \tau g^{H1} & \tau g^{H2} & \tau g^{HH} & \tau g^{HK} & g^H \\ \tau G^K & p^K & \tau g^{K1} & \tau g^{K2} & \tau g^{KH} & \tau g^{KK} & g^K \\ G & T_V & g^1 & g^2 & g^H & g^K & 0 \end{bmatrix}.$$

These signs must be alternatively negative and positive beginning with the first minor marked.[23] We may recall that in the standard case the same condition establishes the convexity toward the origin of the isoquants. In the present case, the same convenient general geometry does not obtain. Only the isoquants of Figure 1b must have this property, a result that follows from the sign of the first minor after p_1 and p_2 are replaced by μg^1, μg^2 on the basis of (34). The existence of a maximum output does not set any simple restriction on the shape of the isoquants $G =$ const. [4].

The introduction of the working day uncovers some unsuspected problems. To begin with, we may distinguish now two planning cost curves.[24] The first, $T(Q; \tau)$ represents the minimum total cost for any given Q when τ is fixed. This function is determined by (30), (31) and the system consisting only of the first three relations of (34). The second planning cost curve $T(Q)$ represents the minimum cost for every Q when τ is free to vary. In this case, the complete system (34) determines also the optimal value of τ for every Q. Naturally, $T(Q) \leq T(Q; \tau)$, the equality prevailing only for those values of Q for which the optimal value of τ coincides with the fixed τ.[25]

In case τ is not fixed, by (30) the last relation

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[22] The new notations in the matrix are self-explanatory; the double superscript denotes a partial derivative of the second order. For the theorem, see, for example, Samuelson [14, p. 378].

[23] If τ is fixed, the same conditions prevail for the reduced matrix obtained by eliminating the last row and the last column from (48).

[24] The term "planning" describes better than "long-run" the situation in which absolutely no factor is fixed.

[25] The dichotomy goes further. There are also two types of *plant* cost curves—one in which τ is free to vary, $T(Q; K)$, and one in which τ is fixed, $T(Q; K, \tau)$. They are derived from (34) by making all $dK = 0$.

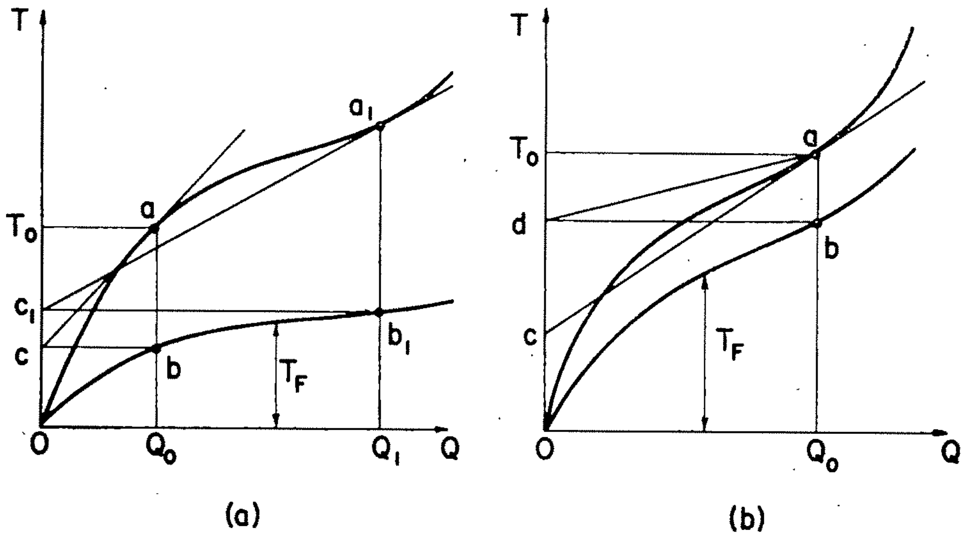

Figure 2

of (34) becomes $T_V=(\lambda+\mu)q$ which further yields

$$(49) \qquad T = (\lambda + \mu)Q + T_F.$$

Let now $T(Q)$ and $T_F(Q)$ be represented graphically in Figure 2a and let ac be the tangent at a to the total cost curve. By (47), the slope of this tangent is $\lambda+\mu$; hence $T_0c=(\lambda+\mu)Q_0=ab$ is the variable, and $Oc=Q_0b$ is the fixed cost $T_F(Q_0)$. If all the variables of g are now kept constant and only τ is allowed to vary, the new total cost is represented by a segment of the straight line ca. All is in order if, as in the situation shown, the marginal cost is decreasing—i.e., if $d^2T/dQ^2<0$. For the resulting cost outside $Q=Q_0$ is greater than the minimum minimorum cost, $T(Q)$. However, if the marginal cost is decreasing—as for the scale Q_1—by varying only τ we obtain a total cost represented by a segment of the tangent a_1c_1 smaller than the minimum minimorum cost. We thus reach the conclusion that marginal cost dT/dQ must *always* be decreasing. The conclusion seems to make sense also from a different angle. From (49) we get

$$(50) \qquad \frac{dT}{dQ} = \mu + \lambda + Q\frac{d(\mu + \lambda)}{dQ} + \frac{dT_F}{dQ},$$

and if we take into account (47), this relation yields

$$(51) \qquad Q\frac{d^2T}{dQ^2} + \frac{dT_F}{dQ} = 0.$$

Since it stands to reason that $dT_F/dQ>0$, we must have $d^2T/dQ^2<0$.

However, this conclusion is not necessarily true. A point which is all too often ignored is that calculus conditions for extrema under constraint fool us whenever the extremum is a corner solution. In case of τ, only $\tau=1$ may be a corner solution. If this is the case, the last equation of (34) is no longer valid. Instead, it is replaced by the corner inequality $T_V<(\lambda+\mu)q$. Also, (49), (51) as well as the geometry of Figure 2a must be discarded. However, (47) still follows from the system (33) modified so as to take into account that $\tau=1$.[26] Therefore, the intercept of the tangent ac still gives $T_0c=(\lambda+\mu)Q$. Only, the variable cost ab is now smaller than T_0c and hence the fixed cost Q_0b is greater than Oc, as shown in Figure 2b. The cost function obtainable by varying only τ is in this case represented by the segment da.[27] Since this cost is greater than the minimum minimorum, all is again in order. The point is that the planning marginal cost does not have to be always decreasing.

Let us also note that $T_V<(\lambda+\mu)q$ may obtain even for a scale for which $d^2T/dQ<0$, such as Q_0 in Figure 2a. But in that case, the optimal arrangement necessarily implies $\tau=1$. For if

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[26] In the modified system $\tau=1$ and $d\tau=0$.

[27] The corresponding optimal value being $\tau=1$, the daily production cannot exceed Q_0.

$\tau<1$, by increasing τ we could again obtain a cost for Q lower than $T(Q)$.

Concluding Remarks

Although the results presented in this paper represent only a first attempt at providing the concept of production process with an adequate analytical representation and at examining the bearings of such a representation on the theory of production, they teach a few general yet vital object lessons. The first such object lesson is that the analytical description of a concept which necessarily involves Change cannot possibly be reduced to the shallow, facile formula of the standard production function. The nature of Change would not have tormented past and present philosophical minds if the problem were that simple. Another object lesson is that time—not in the sense of a dimensional measure as in "sixty miles per hour," but in the full sense of duration—is one of the most important coordinates of any process, hence of any production process as well. Even in the case of a factory—a process which appears to start producing the instant the factory opens—the working time is a valuable economic coordinate which raises some intriguing questions of the sort examined in the last part of the preceding section. The analysis of the process of production brought to light also the fact that the economics of production must take into account not only the working time but also the time of idleness, an issue that distinguishes in a palpable way the economy of farming, especially, from that of manufacturing.

We have also seen that a fitting representation of the simplest production process (that of a factory), even if stripped of many essential but cumbersome components, does not lend itself to an analysis as simple as the seducing geometry of the familiar isoquant map and of the standard cost curves picture. Relations such as (45) and (46), although referring to a highly simplified structure, defeat any attempt at a simple, transparent translation in terms of specific factor productivities, to which the standard theory has accustomed us. The results reached for the total cost function, $T(Q)$, are somewhat simpler and more definite. However, the actual shape of this function is still an open question. The basis from which $T(Q)$ is derived being at least as complicated as the systems (35) and (36) are, it is hard to see how the structure of that function could be directly related to the shape properties of the functions that describe the factory process. In fact, because of the computational facilities offered by the Cobb-Douglas type function, no effort worthy of mention seems to have been directed toward determining the shape properties of the basic function (21) on which most standard works often rely.

The results presented in this paper, it must be emphasized, do not provide us with a set of engineering instructions to be applied in each particular circumstance. But they help us become aware of a series of new problems, some of a paramount importance for policy. It is vain to hope that the production theory may reach the stage when its general analysis will yield practical recipes. There is one crucial fact which we all recognize under examination but otherwise ignore completely. The passage from one fund structure to another in the production of the "same" product does not mean (outside some truly exceptional instances) that some capital funds are increased and some labor funds are decreased (or vice versa). Such a substitution involves above all a qualitative change. True, nothing stands in the way of introducing as many different qualities as we may wish in our production functions *on paper*.[18] Such a feat may indeed clarify some issues, but it does not provide us with an operational basis for cost analysis. In actuality cost analysis is not derived from some gigantic production functions involving all possible qualities of factors. Instead, the decisions are made by comparing the costs of a few possible processes. It would seem, therefore, that the cost analysis of the type propagated by Jacob Viner and amended by E. H. Chamberlin [1, App. B], although not as high in our esteem as that based on production functions, may after all be the more appropriate for the task. As far as factor allocation is concerned, there is only one practical counsel: every marginal dollar must bring the same physical return, which is all that we can really extract from (45) and (46). From all we know, only cost is a fact; the production functions are analytical fictions in a broader sense of the term than the formulas of the natural sciences are. The latter are calculating devices, the former are analytical similes which only help our Understanding to deal with a complex actuality pervaded by qualitative change. All the more necessary it is that these similes should be as faithful as Analysis can allow them to be.

[18] Cf. Georgescu-Roegen [5].

References

[1] Chamberlin, Edward H., *The Theory of Monopolistic Competition*, 6th ed., Cambridge, Harvard University Press, 1948.

[2] Dorfman, Robert, *Application of Linear Programming to the Theory of the Firm*, Berkeley, University of California Press, 1951.

[3] Frisch, Ragnar, *Theory of Production*, Chicago, Rand McNally, 1965.

[4] Georgescu-Roegen, Nicholas, "Fixed Coefficients of Production and Marginal Productivity Theory," *Rev. Econ. Stud.* 3:40–49, Oct. 1935. Reprinted with a 1964 Postscript in Nicholas Georgescu-Roegen, *Analytical Economics: Issues and Problems*, Cambridge, Harvard University Press, 1966, pp. 279–299.

[5] ———, "Measure, Quality, and Optimum Scale," in *Essays in Econometrics and Planning*, ed., C. R. Rao, Oxford, Pergamon Press, 1964, pp. 232–246. Reprinted in *Sankya*, Series A, Part I, 27:36–64, March 1965.

[6] ———, "Process in Farming versus Process in Manufacturing: A Problem of Balanced Development," Ch. 24 in *Economic Problems of Agriculture in Industrial Society*, Proceedings of a Conference of the International Economic Association held in Rome, 1965, eds., U. Papi and C. Nunn, New York, The Macmillan Company, 1969, pp. 497–533.

[7] ———, "Further Thoughts on Corrado Gini's *Delusioni dell' econometria*," *Metron* 25:265–279, 1966.

[8] ———, "Chamberlin's New Economics and the Unit of Production," Ch. 2 in *Monopolistic Competition Theory: Studies in Impact*, ed., R. E. Kuenne, New York, John Wiley & Sons, Inc., 1967, pp. 31–62.

[9] ———, "The Economics of Production," Richard T. Ely Lecture, *Am. Econ. Rev.* 60:1–9, May 1970.

[10] ———, *The Entropy Law and the Economic Process*, Cambridge, Harvard University Press, 1971.

[11] Leftwich, Richard H., *The Price System and Resource Allocation.*, rev. ed., New York, Holt, Rinehart and Winston, 1960.

[12] McLeod, A. N., and F. H. Hahn, "Proportionality, Divisibility, and Economics of Scale: Two Comments, I and II," *Quart. J. Econ.* 63:128–137, Feb. 1949.

[13] Robinson, Joan, *Economics of Imperfect Competition*, London, The Macmillan Company, 1933.

[14] Samuelson, Paul A., *Foundations of Economic Analysis*, Cambridge, Harvard University Press, 1948.

[15] ———, *Economics*, 8th ed., New York, McGraw-Hill Book Company, 1970.

[16] Stonier, Alfred W., and Douglas C. Hague, *A Textbook of Economic Theory*, 2nd ed., New York, Longmans, Green and Co., 1958.

[17] Wicksteed, Philip, *An Essay on the Co-ordination of the Laws of Distribution*, (London, 1894), Reprints of Scarce Tracts, No. 12, London School of Economics and Political Science, London, 1932.

Alternatives to the Neoclassical Theory of the Firm (NTF)*

GLENN L. JOHNSON

SOME of the most useful "Alternatives to the Neoclassical Theory of the Firm" are really modifications and elaborations of the usual neoclassical theory of the firm. Thus, I will define the neoclassical theory of the firm (hereafter NTF) rather narrowly and then discuss both less and more drastic alternatives to it in order to cover more fully various important efforts to find alternatives. The NTF will be discussed from the standpoint of a teacher and researcher long concerned with farm management (private policy) and both domestic and foreign public agricultural policies, programs, and projects (public management). This, along with heavy documentation from the literature of both general and agricultural economics, should be useful to agricultural economists interested in theories of the firm and to general economists interested in the empirical work and ideas of agricultural economists.

For purposes of this paper, I follow Frank Knight's definition of NTF [31]. The NTF I define is based on the law of diminishing returns, *given* a state of the arts, an institutional setting, and a population with constant skills, tastes, wants, preferences, et cetera. It also assumes a given distribution of resource ownership broadly defined to include ownership of rights and institutional privileges of all types as well as physical and human capital. The law of diminishing utility is assumed, though perfect competition is not; perfect knowledge and foresight are. Furthermore, it is assumed that money is a common denominator under perfect knowledge and foresight of all the goods a firm seeks and the bads it avoids, and that utility is a common denominator of all the goods consumers seek and the bads they avoid. There is the additional implicit assumption that the institutional structure within which the firm operates permits free uncoerced trades among perfectly informed individuals. Forced, coerced "trades" are not considered. Theft and robbery are precluded. Because resource owners and consumers are assumed perfectly informed, there are no competitively-forced, non-Pareto better adjustments when firms and households move to equilibrium; instead, they move directly to the equilibrium without overvaluing or overcommitting their resources. Unlike Cyert and March's definition, mine does not preclude monopolies, monopsonies oligopolies, and oligopsonies [7, 52].

The next section will deal with shortcomings of the NTF as defined above and as revealed through use by agricultural economists. The main section classifies alternatives to the neoclassical theory of the firm and deals with them. Attention will be concentrated on accomplishments to date and needed further developments. The final section summarizes the paper.

Shortcomings of NTF Revealed Through Use

Agricultural economists have made heavy use of the NTF defined essentially as above. Before and since World War II, such theory has been used extensively in policy analysis and in marketing extension, advising, and consulting. Since World War II, it has been heavily used in farm management work [23] and more recently in foreign economic development work. Throughout both periods, the NTF has underlaid our supply and demand response and price analyses. More recently, Nerlove [40] introduced some dynamics with distributed lags. Analyses based on the NTF typically explain 65 to 95 percent of the variance in dependent variables. However, changes in the slopes and locations of supply and demand functions are not fully explained by the NTF even when account is taken of changes in technology, institutions, and humans. Some of these inadequacies are due to shortcomings of the NTF with respect to investments, disinvestment, user costs, resource fixity, and opportunity cost pricing [28].

Closely related to investment and disinvestment is the theory of generating savings and creating capital. Many of the fixed durables in firms, especially in agriculture, are used to create capital. When underemployed land and labor are used to generate such durables as cattle, palm trees, vineyards, orchards, irrigation facilities, barns, fences, terraces, etc., these items are increments in real wealth. Most

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GLENN L. JOHNSON *is professor of agricultural economics at Michigan State University.*

such increments in wealth are automatically saved and invested. It is unnecessary for such wealth to be monetized, saved, passed through a central money market, and loaned to producers for investment. All of these processes are short cut. The NTF and its macro counterparts are particularly deficient in this regard. Failure to remedy this deficiency in turn constrains attempts to use the neoclassical theory of the firm to analyze economic growth of less developed economies [24].

Little pre-World War II consulting work with the managers of marketing firms was based on the NTF. The same tended to be true of the work of farm management, extension, and research personnel prior to World War II. Extension advisors relied heavily upon accounting, legal, and, in the case of farm management, technological information. After World War II, farm management researchers and teachers took a much keener interest in the NTF [2, 4, 18]; however, the NTF was used less extensively in advising farmers. In two other articles [21, 23], I have concluded that the reasons include the multidisciplinary breadth of the practical farm management problems faced by extension workers which cannot be handled adequately by NTF, a subtheory of a narrow discipline economics.

At the beginning of World War II, T. W. Schultz pointed out that the NTF did not handle managerial behavior [46] and stressed the need to incorporate dynamic managerial theories into farm management research, extension, and teaching. Several agricultural economists took up the challenge. In doing so, the NTF as modified by Knight, was extended with concepts from such divergent disciplines as statistics, military science, sociology, political science, education and psychology [20]. Such modifications have been used extensively in farm management, but less extensively in agricultural marketing as a result of stress on market structure and performance.

The NTF has been used extensively in designing, executing, and evaluating domestic public policies, programs, and projects. After World War II, this use was expanded to international applications. My own personal experience with farm management and policy research in the less developed countries (LDC's) reveals about the same difficulties with the NTF in those countries as in the U.S.

Used evaluatively, the theory of the firm has helped policy makers and their advisors reach conclusions concerning the welfare consequences of alternative policy programs and projects. This latter use has not always been based upon a clear understanding of the shortcomings of the theory with respect to evaluation of the non-Paretian adjustments which are the objects of many public projects, programs, and policies. In any event, evaluative uses of the neoclassical theory of the firm as embedded in the totality of neoclassical theory reveal serious deficiencies. These deficiencies are with respect to (1) how entrepreneurial units handle normative information, (2) how such values are handled in public affairs management, and (3) difficulties in obtaining objective knowledge of values. In part, the deficiencies seem to grow out of unwise adherence to constraining philosophies about values—particularly positivism and its modifications.

Alternatives to NTF as Defined Above

The preceding discussion of some of the revealed shortcomings of the neoclassical theory of the firm suggests the following classification of alternatives for use in this section:

I. Less drastic static alternatives
II. Less drastic dynamic alternatives
 A. Involving maximization
 B. Premaximization and non-maximization activities of and within the firm
III. Drastic alternatives.

Less drastic, essentially static alternatives to NTF

As Georgescu-Roegen covered a number of important alternatives under this heading, I will concentrate on user costs and investment and disinvestment questions.

Georgescu-Roegen placed recent stress in his preceding paper and in his 1970 Ely lecture on the generation of productive services from stocks [14]. He argues that productive services are generated by stock assets and that, hence, production is best regarded as a function of the functions which generate labor services from laborers, capital services from different forms of capital, and land services from different forms of land. He is fundamentally correct in this and is to be complimented for stressing the inadequacies of the NTF with respect to the stock/flow conversion problem. The stock/flow conversion problem is closely related to the user cost problem addressed by Keynes at the macro level and largely ignored by general economists at the micro level [30].

At the micro level, agricultural economists have had considerable experience with the stock/flow conversion problem. In the long production chains of vertically combined agricultural production processes, stock/flow conversions are encountered repeatedly but are not adequately handled.

The user cost problem involves the economics of deciding on the optimum rate at which to generate services from durables. Until the economics of determining the optimum rate is known, optimum rates of disinvestment and investment are unknowable in theory. And until optimum rates of disinvestment and investment are knowable in theory, the theory of the growth, stagnation, and/or decline of the firm remains vague and underdeveloped. Among research efforts revealing the damaging consequences of not handling investment and disinvestment adequately are the Lake State Dairy Adjustment Study [48] and the North Central Feed-Grain/Livestock Adjustment Study, NC54 [6]. Both were primarily linear programming efforts. Neither handled off-farm migration, farm consolidation, or major labor-saving capital investments well enough to evaluate or predict the consequences of alternatives with acceptable reliability. Two substudies, however, of the feed grain/livestock effort did demonstrate that results could be improved with better, but still inadequate, investment and disinvestment (alternatively, asset fixity of variability) theory [32, 41]. Off-farm migration can be better explained with than without such theory [49].

As linear programming (LP) is an application of the NTF based on a reconception of the production function which permits simplification of mathematical computation for locating optima, I will not treat it is as an alternative. One of the important accomplishments of linear programming, however, has been to help clarify the nature of opportunity costs with explicit recognition of acquisition costs/salvage value differentials for the factor of production involved [10; 28,Ch. 3,section on opportunity cost]. The use of linear programming in studying investment and disinvestment problems and, hence, firm growth and deterioration, however, has been limited by failure to solve the user cost problem discussed above.

Less drastic, more dynamic alternatives to NTF

The word dynamic is used here to mean nonstatic. As such, it includes simple systems based upon postulated rates of change through time and still more elaborate systems involving the activities of learning, problem-solving entrepreneurs operating in the presence of imperfectly known stochastic changes.

A simple way of creating a dynamic alternative to NTF is to introduce rates of change from one time period to the next. This makes it necessary to date variables [19] and leads to endless opportunities to manipulate time derivatives sometimes relevantly and often irrelevantly.

A more complicated modification is to introduce probability distributions. Once probability distributions are introduced, it is possible to start analyzing the inter-period chance-taking, risk-averting, and insuring activities of the firm managers [16, 17, 31, 36].

The further introduction of the possibility of learning more about probability distributions with the passage of time permits analysis of the complicated learning roles which managers play [17, 51]. The development of sequential analysis in statistics made it possible to include sequential decision-making theory from statistics as an integral part of the theory of the firm and as a part of a theory of management. Several modern writers have emphasized processes in their attempts to develop the theory of the firm [5, 7, 36].

New theories of the firm and management based on ideas borrowed from mathematics and statistics inevitably reflect the state of those disciplines. The early Knightian theory was conditioned by single sampling statistical concepts, while current theories of the firm and management can and some do reflect Wald's sequential analysis [20]. Since Wald, there have been other developments in statistical decision theory such as the development of decision rules including the minimize regret, satisficing rules, etc. Baysesian statistics have legitimized utilization of prior information from a great variety of sources and, as such, have helped us more flexibly and realistically to conceptualize managerial processes and activities. Closely related to the ideas borrowed from statisticians are those borrowed from mathematicians and military strategists. For example, the theory of games helps analyze the interpersonal relationships among managers of interacting firms and even among persons within the managerial units of large firms [7].

Such theories of the firm and management

have contributed considerably to the teaching of farm management and, to a lesser extent, of marketing firm management. However, such theories have been little used to undergird supply, demand, program, and policy analyses.

Expectation models were first developed with respect to prices and then yields. Simple, naive price expectation models have been used, the most complex of which tend to be distributed lag models [40]. Later the Interstate Managerial Study (IMS) examined the formation of expectations with respect to technological, institutional, and human change and performance [32]. It concentrated heavily on managerial functions and processes and is highly empirical, being based on data from 1075 farm entrepreneurs. Though the IMS deals with processes, the emphasis is on observation, analysis, decision making, execution, and responsibility bearing rather than on goal formation, conflict resolution, uncertainty avoidance, problemistic search, and organizational learning as in the works of Cyert with March [7] and Cohen [5] and Mack [36]. A north central states farm management study, NC59, avoided study of processes while concentrating on biographical antecedents and outcomes. It did not lead to a citable overall publication. Thus, all three lines of work indicate the importance of processes for dynamic theories of the firm. Processes are as important in management as in production.

Incidentally, I believe it is advantageous to treat management activities as theoretically distinct from product-producing activities. The management unit can be viewed as a separate enterprise producing managerial decisions which, of course, control the enterprises producing other services and goods.

The IMS revealed that the NTF provides basic concepts to farmers (1) forming price expectations and (2) analyzing resource use and farm organization questions resulting from price changes [47]. It also confirmed the importance of the Friedman-Savage utility hypothesis and produced cardinal measurements of the utility of wealth [15]. The IMS further confirmed the usefulness of the Frank Knight/Wald ideas in classifying degrees of knowledge [27]. Virtually no applications of dynamics have been made by agricultural development specialists, domestic or foreign. The same is often true of persons working on such domestic subjects as environmental quality, poverty, public investment, etc., though works by Ruttan and Hayami [43], Ruttan [42], and Schultz [44] are outstanding exceptions.

Another interesting development among dynamic theories of the firm has to do with the consequences of recognizing simultaneously that acquisition costs for the durables which generate productive services are typically greater than their salvage prices and that entrepreneurs have imperfect knowledge. The consequences of acquisition/salvage price differentials were discussed above. We turn now to a discussion of errors made in committing durables to firms and specific production processes in the presence of imperfect knowledge. Durables are often erroneously committed in such a way that the services they generate have ex post marginal value productivities less than sufficient to cover acquisition costs and more than sufficient to cover salvage prices. In such circumstances, the resource is fixed and use of the opportunity cost principle is required to insure proper allocation of the use of the services produced by the fixed durable [3; 20, Ch. 10; 22; 28].

It is also interesting to note that in the absence of interpersonally valid utility measures, the new Pareto optima resulting from errors of entrepreneurs cannot be judged to be either inferior or superior to the optimum which would have existed had such errors not been made. Thus, the theory of second best applies to the loss-minimizing adjustments for the consequences of the original error constrains the entrepreneurs to a different set of alternatives than the original Pareto-better set [12, 28, 29, 35].

Keynesian theories deal with liquidity preference as well as with the marginal efficiency of capital and user cost. Dynamic micro theories of the firm deal with flexibility and flexibility reserves as a means (with a cost) of permitting managers to learn [17, 34, 51]. This has permitted capital rationing concepts to be extended from risk discounting (an insurance adjustment) [45] to include consequences of establishing flexibility reserves [4, pp. 395–403]. These are similar to Keynesian concerns with liquidity preference, stagnation, investment, user costs, etc., the macro equivalents of micro concerns with flexibility, stability, growth, and deterioration of firms, industries, and sectors. Thus, macro analyses and studies of the economy raised severe questions in the minds of economists concerning the NTF which

have been shared and made even more explicit by the empirical micro research of agricultural economists.

In those forms of dynamic economics involving probability distributions and possibilities of learning, it becomes difficult to distinguish between the firm as a profit maximizer and the household as a utility maximizer. Von Neumann and Morgenstern [50] and Friedman and Savage [13] have demonstrated that insuring and chance-taking can involve maximization of expected net utility instead of expected money income. This has led to theories of the firm designed to explain the consumption and utility-maximizing activities of the firm and/or associated household or households, if any. In disadvantaged areas of the U. S. and in the LDC's this consideration is particularly important; however, the need to consider non-monetary values in the theory of the firm is universal and does not support the need for a special theory for LDC firms despite attempts to distinguish between traditional and modern agriculture [39, pp. 37–46].

A recent masterful review [9] of Bernoullian decision theory in agriculture asks "if utility is futility?" and argues strongly and effectively that utility is "the best possible approach to risky choices in agriculture." While there is uncertainty about the "best possible" in the quote, the usefulness of the utility concept in the theory of the firm seem to be established.

Alternative theories of the firm have also been generated by borrowing concepts from such disciplines as political science, sociology, psychology, and education for use in developing the managerial aspects of the dynamic theory of the firm. These concepts have been woven into the NTF to produce new maximizing of theories for deciding on right actions [11, 33]. They have also been much more useful than NTF in helping managers interpret the meaning of the psychological, institutional, and sociological data required to solve the multidisciplinary problems they face. It is interesting to note that though much entrepreneurial behavior is not of a maximization nature, a great part is rational and premaximization in nature.

Let us look specifically for a possible theory of rational premaximization behavior. When entrepreneurs face decisions concerning a number of disparate acts involving technological, institutional, and human change, the preconditions for application of maximization techniques are typically absent, at least initially. First, the manager needs to acquire normative knowledge, i.e., knowledge of good and bad per se as opposed to both positive knowledge and to knowledge of right and wrong [25, 26, 33], the latter depending on both normative and positive knowledge. Normative knowledge determines the trade-offs among the alternative consequences of acts and provides objective functions for maximization. Further, if alternative actions affect the welfare of more than one person within the concern of the firm and some adversely, knowledge of the trade-offs must take on interpersonal validity. Thus, a precondition for maximization *is attainment of a normative common denominator with interpersonal validity* among the goods and bads involved in a managerial decision. In addition, disparate acts involving changes in technology, institutions, and human behavior should not be expected to conform to anything like the laws of diminishing utility and productivity, not at least until a considerable amount of premaximization investigation has *arranged the acts in the order of their descending net advantage per unit of some sacrificed alternative.* Much of such investigation deals with technology, institutions, and human phenomena better handled by disciplines other than economics [7, 34, 38]. Another precondition is an *agreed upon decision-making rule.* Under perfect knowledge, the decision-making rule is simple; management merely maximizes the difference between good and bad, provided of course it has a valid common denominator and has solved the order problem discussed above. However, under imperfect knowledge the situation is much different. Alternatively, one might use the rule of maximizing the present value of expected future net returns or one might maximin, satisfice, or shoot for the moon. In the absence of an interpersonally valid common denominator, decision may still be mandatory; in such cases the decision rule may be left to chance (i.e., drawing straws of draft lottery numbers), voting, or fighting [1].

Because managerial activity is highly rational and involves problem-solving activities, there is generally an ultimate objective of maximizing something, once the preconditions for maximization are met. As the NTF automatically meets the preconditions for maximization, its students have tended to neglect premaximizing as both activities of managers and a topic in theory. In practice, however, farm

management and marketing researchers, advisors, and consultants have commonly encountered situations in which the premaximization conditions were not met. Many kinds of information have been used from a great variety of sources unconstrained by special theories, analytical techniques, or philosophic positions. Paper and pencil projections as well as mental calculations concerning consequences of alternative courses of action have led to the establishment of the preconditions for maximization [4, Ch. 25 and exercise 20, pp. 420–21]. Some less effective advisors and consultants have neglected the necessity of establishing the preconditions for maximization and have in a sense committed perjury consciously or unconsciously, i.e., they have falsely assumed or pretended that the preconditions have been met and then proceeded directly to application of maximization principles from the NTF. Extensive attention to maximization activities to the neglect of premaximization activity does not seem to be a very advantageous approach.

Macro-neoclassical theory in general and the NTF, in particular, are deficient with respect to how entrepreneurs and entrepreneurial units handle value questions. The deficiency appears to grow out of both neglect and unduly specialized (and at times unconsciously adhered to) highly specialized philosophic orientations [25, 26, 37]. Some of the most important issues before society these days involve non-Pareto better changes with respect to ownership of property, skills, rights, and privileges; environmental quality, consumer protection, population size, socio-politico-economic structures, etc. The NTF and of the household cannot contribute much to the macro evaluation of such changes when constrained by the modified positivism of Pareto-better welfare economics. Instead, we need to base both micro and macro theory on philosophic orientations which permit the application of logic and empirical procedures to normative phenomena as discussed above. We have been bound too long by positivism, that philosophy which no longer dominates science. Among modern attempts to deal with goal formation in the theory of the firm are those by Cyert, March, and Cohen. These investigators fail to distinguish between concepts of goodness and badness or values per se and goals, the latter being defined implicitly as that which the firm will try to do. Thus, little explicit attention is given to value as distinct from goal formation with the firm [5, 7]. IMS researchers (and the author was one) also neglected values conceptually, but were pressed to consider them by the data they gathered [20, Ch. 9]. Both the Cyert and IMS groups suffered from unduly specialized philosophic orientations, the Cyert *et al.* orientation being unduly individualistic [7, pp. 26ff] and the IMS being unwisely conditionally normative [20, Chs. 4 and 10; 30.]

An alternative to NTF which concentrates on the neglected, rational, premaximization activities of managers seems to be emerging from the work of systems scientists and simulators. Currently, project, program, and policy analysts for both private and public decision makers are paying increased attention to the generalized, computerized, systems-science, simulation approach to evaluative studies of projects, programs, and policies. Premaximization questions are encountered in these studies. The approach is general in that it uses any specialized technique such as LP, input/output analysis, simultaneous equations, etc., as appropriate to estimate the consequences of following alternative courses of action through time. It is also general in that it utilizes different kinds and sources of data and information as appropriate. When the projections produced by simulation studies are examined in close interaction with decision makers, they help resolve the four difficulties discussed above [7, pp. 312ff; 8; 37].

In the interactions, information about values, including utility, is improved by (1) logical analysis to determine interval consistency of the body of positive and value concepts being used; (2) checks for consistency with new positive and value concepts formed from new observations and experience; (3) checks for clarity, i.e., lack of ambiguity; and (4) checks for workability. Used jointly these four tests circumvent constraints of specialized philosophies on the attainment of normative knowledge as discussed below. Personally, I find in the simulation approach a hope for a theory of the firm more useful for predictive, evaluative, and prescriptive work. There now seems to be less reason to worry about utility and value concepts being tautological and unobservable. "Good," "bad," and utility can be regarded as primitive undefined terms such as mass and distance in physics. And the question of whether they can be experienced can be answered on the basis of whether one does or does not experience the badness, say, of injus-

tice or the goodness of income after poverty or of a clean unpolluted environment after pollution instead of on the basis of blind adherence to effete positivism [25, 33].

Drastic alternatives to NTF

One can conceive of alternatives to the NTF so drastically different that similarities with NTF hardly exist. Such alternatives originate in sociology, psychology, political science, and the physical sciences. Managerial behavior is recognized to be social, psychological, and political in nature. Even individual entrepreneurs and family members interact much as members of corporate managerial units interact with each other in sociological and political processes. All entrepreneurs and all members of entrepreneurial units are human beings; thus, psychology is relevant. Further, entrepreneurial units, whether individualistic or multiperson, are involved in learning and in problem-solving activities; thus, education or learning theories are relevant as are philosophic theories having to do with learning and problem solving. Even research methodologists can claim relevance, for the managerial unit can also be viewed as a research unit engaged in research on the problems of the firm. Most production is technical; thus, engineering and the physical sciences are also relevant.

As I see it, the prospects for specialized theories of the firm based on any single discipline are poor. Specialization on economies did not produce an adequate theory of the firm. It is not probable that specialization on psychology, political science, sociology, technology, etc., will either, howevermuch such disciplines can and do contribute to our understanding of limited parts of the structures and activities of managerial units.

At this point, it is worthwhile asking about the prospects for a truly general interdisciplinary theory of the firm, there being, to the author's knowledge, no such theory in existence. Experience to date and logic indicate that the prospects are poor. *First*, though the theories involving more than one discipline which have been developed to date have earned some acceptance in teaching and consulting, they are seldom used at macro and semi-macro levels for policy and program analysis, design, and evaluation. Each seems unduly specialized and not broadly applicable for reasons discussed further. *Second*, each of the involved disciplines is in need of much development, yet is now so complex as to be unmanageable by all except a few exceptional members of each discipline. The second consideration means that we should expect interdisciplinary efforts to be conglomerations of parts of partially developed disciplines. Managers face numerous highly complex problems. These problems involve widely varying disciplinary mixes. Thus, it appears unlikely that we will be able to develop and master a general theory of the firm capable of handling all of the problem-solving activities of managers and firms. This is not to state, however, that managerial units cannot solve their problems. If the management of a firm takes its problems one at a time, an appropriate ad hoc multi-disciplinary mix of skills and theories can often be assembled for each problem. Each member of an appropriate team of disciplinarians can bring the full power of his discipline to bear on the particular problem at hand. Among those disciplinarians will be for some problems economists who will use the traditional NTF or supply and demand functions based on it with far more finesse and in far more detail than could be mastered by a person or contained in a single theory trying for equal finesse in all disciplines possibly relevant for all problems. The same is true for the other disciplines. It appears that for a long time to come, we will have to get along with alternatives to the NTF constructed by adding components to NTF from other disciplines. We can expect to have a large number of such alternatives each with a different range of applicability.

Summary

(1) The traditional NTF (neoclassical theory of the firm) or alternatives based substantially on it provide the main underpinning for our economy and industry wide supply demand and response studies. This is true for both prescriptive and predictive work.

(2) Much progress has been made in developing alternatives to the NTF, resulting mainly from incorporation of concepts and ideas from other disciplines into NTF. These modifications have been most useful at the micro teaching and consulting levels and less useful to researchers on practical macro-level problems, teachers, and consultants. I believe this will continue to be the best way to make progress on the theory of the firm.

(3) If the theory of the firm is to continue to be predictive as well as evaluative and pre-

scriptive, it will continue to be of a maximization nature though substantial additional attention needs to be devoted to premaximization, i.e., to determination of interpersonally valid, normative common denominators of "goods" sought and "bads" avoided; to ordering alternative actions in terms of decreasing net advantage per unit of sacrificed good; and to determining appropriate decision-making rules.

(4) Because of the importance of values in decision making, new alternative theories of the firm should not be constrained by philosophies which limit description and analysis of values—specifically, positivism is too restrictive as is Pareto-better welfare economics. Even pragmatism is restrictive in its complexity.

(5) Utilitarianism remains a viable, though not entirely adequate, philosophy for the theory of the firm; however, it has to be supplemented by procedures for handling multiple objectives in the premaximization stages and ways of making decisions in the absence of a normative common denominator, such as utility itself, in case such a common denominator cannot be found.

(6) Paper and pencil projections have a long record of usefulness to both public and private decision makers. A modern equivalent is generalized, computerized, systems science simulation. Both of these are important potential contributors to the theory of the firm.

(7) One cannot anticipate success in developing a generally applicable interdisciplinary theory of the firm in the near future; instead, it is more realistic to anticipate a large number of theories involving different classes of problems encountered by different classes of firms.

(8) I doubt that the consistent differences between nonfarm and farm firms are important enough to justify separate theories; rather, I think we have to settle for a package of partial theories for use as appropriate in either case. I believe the same to be true for firms in the developed and less developed countries.

References

[1] Arrow, Kenneth J., *Social Choice and Individual Values*, New York, John Wiley & Sons, Inc., 1951.

[2] Black, John D., *Introduction to Production Economics*, New York, Henry Holt and Co., 1926.

[3] Boyne, D. H., and G. L. Johnson, "A Partial Evaluation of Static Theory from Results of the Interstate Managerial Study," *J. Farm Econ.* 40:458–468, May 1958.

[4] Bradford, L. S., and G. L. Johnson, *Farm Management Analysis*, New York, John Wiley & Sons, Inc., 1953.

[5] Cohen, Kalman J., and Richard M. Cyert, *Theory of the Firm: Resource Allocation in a Market Economy*, Englewood Cliffs, N.J., Prentice-Hall, Inc., 1965.

[6] Colyer, Dale, and George D. Irwin, *Beef, Pork and Feed Grains in the Cornbelt: Supply Response and Resource Adjustments*, University of Missouri Agr. Exp. Sta. Res. Bull. 921, August 1967.

[7] Cyert, Richard M., and James G. March, *A Behavioral Theory of the Firm*, Englewood Cliffs, N.J., Prentice-Hall, Inc., 1963.

[8] Dent, J. B., and J. R. Anderson, *Systems Analysis in Agricultural Management*, Australia Party, John Wiley & Sons, Ltd., 1971.

[9] Dillon, John L., "An Expository Review of Bernoulian Decision Theory," *Australian Rev. Marketg. & Agr. Econ.* 39:3–77, March 1971.

[10] Dorfman, Robert, P. A. Samuelson, and Robert M. Solow, *Linear Programming and Economic Analysis*, New York, McGraw Hill Book Co., 1958.

[11] Ferguson, C. E., *The Neoclassical Theory of Production and Distribution*, Cambridge, The Cambridge University Press, 1969.

[12] Fishlow, Albert, and Paul A. David, "Optimal Resource Allocation in an Imperfect Market Setting," *J. Polit. Econ.* 69:529–546, Dec. 1961.

[13] Friedman, Milton, and L. J. Savage, "The Utility Analysis of Choices Involving Risks," *J. Polit. Econ.* 56:279–304, 1948.

[14] Georgescu-Roegen, Nicholas, "The Economics of Production," *Am. Econ. Rev.* 60:1–9, May 1970.

[15] Halter, Albert N., "Utility of Gains and Losses," in *A Study of Managerial Processes of Midwestern Farmers*, eds., Glenn L. Johnson, Albert N. Halter, Harald R. Jensen, and D. Woods Thomas, Ames, Iowa State University Press, 1961, pp. 128–139.

[16] Hardy, C. O., *Risk and Risk Bearing*, Chicago, University of Chicago Press, 1923, pp. 54ff.

[17] Hart, A. G., "Risk, Uncertainty and the Unprofitability of Compounding Probabilities," in *Readings in the Theory of Income Distributions*, Philadelphia, The Blakiston Co., 1946, pp. 547–557.

[18] Heady, Earl O., *Economics of Agricultural Production and Resource Use*, Englewood Cliffs, N.J., Prentice-Hall, Inc., 1952.

[19] Hicks, John R., *Value and Capital*, Oxford, Clarendon Press, 1938.

[20] Johnson, Glenn L., Albert N. Halter, Harald R. Jensen, and D. Woods Thomas, eds., *A Study of Managerial Processes of Midwestern Farmers*, Ames, Iowa State University Press, 1961.

[21] Johnson, Glenn L., "Agricultural Economics, Production Economics, and the Field of Farm Management," *J. Farm. Econ.* 39:441–450, May 1957.

[22] ———, "Supply Function—Some Facts and Notions," in *Agricultural Adjustment Problems in a Growing Economy*, eds., Earl O. Heady, Howard G. Diesslin, Harald R. Jensen, and Glenn L. Johnson, Ames, Iowa State College Press, 1958, pp. 24–93.

[23] ———, "Stress on Production Economics," *Australian J. Agr. Econ.* 7:12–26, June 1963.

[24] ———, Orlin J. Scoville, George K. Dike, and

CARL K. EICHER, *Strategies and Recommendations for Nigerian Rural Development*, East Lansing, Consortium for the Study of Nigerian Rural Development, CSNRD 33, July 1969.
[25] JOHNSON, GLENN L., *The Role of the University and Its Economists in Economic Development*, Guelph, Department of Agricultural Economics, AE 70/2, March 1970.
[26] ———, "The Quest for Relevance in Agricultural Economics," Fellows Address, American Agricultural Economics Association, Carbondale, Ill., Aug. 17, 1971; *Am. J. Agr. Econ.* 53:729–739, Dec. 1971.
[27] ———, AND CURTIS LARD, "Knowledge Situations," in *A Study of Managerial Processes of Midwestern Farmers*, eds., Glenn L. Johnson, Albert N. Halter, Harald R. Jensen, and D. Woods Thomas, Ames, Iowa State University Press, 1961, pp. 41–54.
[28] JOHNSON, GLENN L., AND LEROY QUANCE, *The Overproduction Trap*, Baltimore, The Johns Hopkins Press, 1972, forthcoming.
[29] JOHNSON, HARRY G., "The Cost of Protection and the Scientific Tariff," *J. Polit. Econ.* 68:327–345, Aug. 1960.
[30] KEYNES, JOHN M., *The General Theory of Employment, Interest and Money*, London, Harcourt, Brace and Co., 1935.
[31] KNIGHT, FRANK H., *Risk, Uncertainty and Profit*, New York, Houghton Mifflin Co., 1921.
[32] LARD, CURTIS F., "Profitable Reorganizations of Representative Farms in Lower Michigan and Northeastern Indiana with Special Emphasis on Feed Grains and Livestock," unpublished Ph.D. thesis, Michigan State University, 1963.
[33] LEWIS, C. I., *The Ground and Nature of the Right*, New York, Columbia University Press, 1955.
[34] LINDER, STEFFAN, *The Harried Leisure Class*, New York, Columbia University Press, 1970.
[35] LIPSY, R. G., AND KEVIN LANCASTER, "The General Theory of Second Best," *Rev. Econ. Studies* 24:11–32, 1956–1957.
[36] MACK, RUTH, P., *Planning on Uncertainty*, New York, John Wiley & Sons, Inc., 1971.
[37] MANETSCH, THOMAS J., MARVIN HAYENGA, ALBERT N. HALTER, *et al.*, *A Generalized Simulation Approach to Agricultural Sector Analysis with Special Reference to Nigeria*, East Lansing, Michigan State University Press, 1971.
[38] MAWBY, RUSSELL, AND CECIL HAVER, "Types and Sources of Information Used by Farmers," in *A Study of Managerial Processes of Midwestern Farmers*, eds., Glenn L. Johnson, Albert N. Halter, Harald R. Jensen, and D. Woods Thomas, Ames, Iowa State University Press, 1961, pp. 24–40.
[39] MELLOR, JOHN W., "Toward a Theory of Agricultural Development," in *Agricultural Development and Economic Growth*, eds., Herman M. Southworth, and Bruce F. Johnston, Ithaca, Cornell University Press, 1967, pp. 37–46.
[40] NERLOVE, MARC, *The Dynamics of Supply: Estimation of Farmers Response to Price*, Baltimore, The Johns Hopkins Press, 1958.
[41] PETIT, MICHEL J., "Function d'offre, Approche Dynamique," *Econ. Rurale*, Vol. 63, Jan.–March 1965.
[42] RUTTAN, VERNON J., "Technology and the Environment," Presidential Address, American Agricultural Economics Association, Carbondale, Ill., Aug. 17, 1971; *Am. J. Agr. Econ.* 53:707–717, Dec. 1971.
[43] ———, AND YUJIRO HAYAMI, *Agricultural Development: An International Perspective*, Baltimore, The Johns Hopkins Press, 1971.
[44] SCHULTZ, T. W., *Investment in Human Capital*, New York, The Free Press, 1971.
[45] ———, "Capital Rationing and Tenancy Reform," *J. Polit. Econ.* 58:309–325, 1940.
[46] ———, "Scope and Method in Agricultural Economics Research," *J. Polit. Econ.* 47:705–717, Oct. 1939.
[47] THOMAS, D. WOODS, AND DALE KNIGHT, "Analytical Process in Farm Management," in *A Study of Managerial Processes of Midwestern Farmers*, eds., Glenn L. Johnson, Albert N. Halter, Harald R. Jensen, and D. Woods Thomas, Ames, Iowa State University Press, 1961, pp. 55–84.
[48] University of Minnesota, *Equilibrium Analysis of Income Improving Adjustments on Farms in the Lake States Dairy Regions, 1965*, Agr. Exp. Sta. Tech. Bull. 246, 1963.
[49] VENKAREDDY, CHENAREDDY, AND G. L. JOHNSON, "Projection of Age Distributions of Farm Operators in the U.S. Based Upon Estimates of the Present Value of Incomes," *J. Farm Econ.* 50:606–620, 1968.
[50] VON NEUMANN, JOHN, AND OSKAR MORGENSTERN, *Theory of Games and Economic Behavior*, Princeton, Princeton University Press, 1947.
[51] WALD, ABRAHAM, *Sequential Analysis*, New York, John Wiley & Sons, Inc., 1947.
[52] WOLFE, J. N., "Theory of the Firm," in *International Encyclopedia of Social Science* 5:455–459, 1968.

Discussion: J. EDWIN FARIS, *Virginia Polytechnic Institute and State University*

Drs. Georgescu-Roegen and Johnson have each presented a scholarly paper. Yet one might question the contributions made by these papers toward an understanding of the theory of the firm. It appears that both authors have written with the graduate student as their primary audience. In this sense, I believe that they have made an excellent contribution. For practicing agricultural economists, however, there appears to be very little new in these papers except for their excellent organization.

Professor Georgescu-Roegen uses somewhat different terminology. However, the preciseness with which he defines the terms is good and useful. The discussion in the section "Process: An Analytical Tangle" is excellent. In the following section, "The Elementary Process: A Fundamental Concept," much is made over the difference between the factory and farm systems of production. It appears that this distinction is somewhat arbitrary and unnecessary except that it allows Professor Georgescu-Roegen to

be a little more specific in his later statements concerning waste, idleness, and economic development when considering only factories.

Georgescu-Roegen is apparently not familiar with some of the recent developments in feedlot operations that approximate factories. Also, many farm operators attempt to utilize some factors for longer periods of time by planting different field or tree crops requiring use of these factors at different peak periods.

Agricultural economists (and managers) have realized for years that "overhead" or "fixed" costs affect the per-unit cost of production. In the mid-1960's there was a rash of studies on economies associated with size that stressed this point, among others. This stress on the "economy of capital utilization" is important. It has had quite an effect upon farm size, although perhaps in a somewhat indirect manner.

The statement, "It is the fact that what differentiates one factory from another is the size of the waste flow, i.e., the amount of the input flows that goes to waste," is not well defended in this paper. Technical idleness is "bad." Yet, to utilize a particular resource more fully may be economically infeasible when examined in light of the total system on the availability of other resources. With respect to the latter, the combination of capital applied to labor could be the more important item.

Although Georgescu-Roegen has emphasized somewhat different aspects of the theory of the firm, French, Sammet, and Bressler presented most of the concepts in a publication in the 1950's [2].

One major concept was omitted in the papers presented by both Georgescu-Roegen and Johnson. This concept is that of replacement. In considering replacement, it has been shown that the optimum time to replace an asset (fund) is dependent upon whether or not immediate replacement of the asset is anticipated [1]. Thus, the optimum length of the production process for feeder cattle is dependent upon whether or not the facilities are to remain idle for some time or if a new lot of feeder cattle is to use the facilities immediately. It is not surprising Georgescu-Roegen finds that " . . . even in the case of a factory system the optimal factory does not depend on the prices of factors *but also on the production time* . . . ." Johnson discusses the asset fixity concept but not particularly in relation to replacement.

Johnson's definition of the neoclassical theory of the firm is somewhat narrow but precise. The shortcomings of this theory are well presented, especially that of the formation of capital outside the central money market. Yet, in his further discussion of the problems of investment and disinvestment, he did not delve very deeply into this area. It is interesting that a number of farm operators are not very successful financially until they sell their land. Thus, they must leave farming to reap the benefits of appreciation in land values.

The "Less Drastic Dynamic Alternatives" to the NTF appear to result from imperfect knowledge. Techniques used to handle imperfect knowledge are discussed. Johnson states, "Personally, I find in the simulation approach a hope for a theory of the firm more useful for predictive, evaluative, and prescriptive work." Perhaps, but simulation is more of a technique than a theory. Simulation has the advantage of making the researcher specify the parameters and relationships concisely. This of course was one of the greatest attributes of linear programming.

I am surprised that "externalities" and associated problems were not specifically mentioned. Also, certain institutional arrangements such as bargaining associations were not mentioned except as not being permissable under the neoclassical theory of the firm. Certainly such institutional arrangements are apt to occupy an important role in the agricultural sector in the next decade.

The discussion by Johnson in the last section is especially good. Interdisciplinary efforts using our special expertise will be a *must* for many of the problem areas that we can and should be involved in at the present time.

References

[1] FARIS, J. EDWIN, "Analytical Techniques Used in Determing the Optimum Replacement Pattern," *J. Farm Econ.* 42:755–766, Nov. 1960.

[2] FRENCH, B. C., L. L. SAMMET, AND R. G. BRESSLER, "Economic Efficiency in Plant Operations with Special Reference to the Marketing of California Pears," *Hilgardia* 24:543–721, July 1956.

THEORY OF THE FIRM IN A NON-MARKET ENVIRONMENT

CHAIRMAN: W. D. TOUSSAINT, North Carolina State University

An Analysis of the Market for Food Stamps*

W. KEITH BRYANT

THIS paper represents an attempt to analyze the Food Stamp Program (FSP) not as a farm program or a welfare program but rather as a market for a publicly supplied good. The analysis, therefore, concentrates on the forces determining the demand for and the supply of food stamps, and is conducted in an attempt to contribute to an economic theory of public and non-profit sectors of the economy, a subject neglected by economists until recently.

The analysis of the FSP is not important in itself, for it is one of those programs the poor rightly claim has been studied too much and changed too little. Hoover and Maddox [4], Kotz [7], Nelson [8], Paarlberg [11], Segal [12], and Steiner [13], among others, have made studies of the various aspects of this and other food programs. Instead, it is intended to be a case study, because the FSP is representative of a large number of public and non-profit activities. The FSP is characterized by a bureau which operates the program and which faces not only a legislature from which it obtains an annual appropriation but also the eligible households to which it sells the service it produces—namely, food stamps. Colleges, some hospitals, child adoption agencies, and YMCA's are among the diverse activities and institutions which share these characteristics. The FSP was chosen because it is a relatively simple example of this type of activity and because the author had some knowledge of the program. If the analysis explains the behavior of the FSP, then perhaps it can be applied to explain the behavior of similar programs and activities.

The model developed in this paper is an extension of a model of a "pure bureau" developed by Niskanen in 1968 [9]. A pure bureau in his terminology is one which trades its output for a budget. The extension is to what Niskanen called a "mixed bureau"—one that not only exchanges its output for a budget but also sells it at a unit price. The Food and Nutrition Service (FNS) of the USDA, the agency which administers the FSP along with other food programs, obviously is a mixed bureau. Niskanen has provided his own analysis of the mixed bureau as well as of other types of bureaus in a recently published book [10]. This analysis of the FSP can be viewed as a modification and application of his model.

Two models of the market for food stamps are developed. To test the models certain price and output implications of the model are then developed and confronted with the history of the FSP. The test is unsatisfactory in the sense that data do not exist to estimate the complete models.

A Model of the Market for Food Stamps

There are four components to the structure underlying the market for food stamps. The *first* component is the Congress which authorized the program and outlined its details in the Food Stamp Act of 1964 and in amendments in 1967, 1968, and 1971 (P.L. 88-525, P.L. 90-91, P.L. 90-552, and P.L. 91-671). It appropriates money annually to operate the program and constrains the program informally via appropriations hearings and the like.

The *second* component is the FNS, the agency within the USDA which administers the program.[1] It administers some six child-feeding programs and two family food assistance programs of which the FSP is one. For our purposes the FNS can be viewed as operating three programs: the FSP, the Food Distribution Program (FDP)—the legal substitute for the FSP,[2]

* A revision and extension of [1]. University of Minnesota Staff Paper P71-31, December 1971. The author acknowledges helpful discussions of this subject from colleagues at the Universities of Minnesota and Wisconsin and with members of the now-defunct NCR-77. Martin Abel, Lee Martin, and William Niskanen are due special thanks. They are, of course, absolved of any errors in this paper.

W. KEITH BRYANT *is professor of agricultural economics at the University of Minnesota.*

[1] Although the Consumer and Marketing Service administered the program until 1969, the bureau will be referred to as FNS for simplicity.

[2] The FDP is the program under which food is distributed free to low-income families in counties participating in the program. Prior to 1971 it was called the Commodity Distribution Program.

and all other programs. The FNS is the sole-source supplier of the FSP and FDP to local welfare departments which make up the *third* component of the market.

Given that the states in which they are located have agreed to accept either the FDP or the FSP, local welfare departments choose to operate either one or none of the two programs —legally they cannot offer both. If the FSP is chosen, the local welfare department administers the program locally, certifying households as eligible to participate, arranging for stamp receipt centers and the times during the month they are open for business, and administering the sale of stamps. The households eligible to participate in the FSP constitute the *fourth* component.

The analysis in this paper is set at the federal level and suppresses relations between local welfare departments and households and between the FNS and local welfare departments. Consequently, the FNS is viewed as a sole-source supplier of the FSP and its competing program the FDP, constrained in its behavior by Congressional appropriations and intent, by the costs of running the programs, and by the demands for the programs on the part of eligible households. The FNS, therefore, derives revenue from appropriations and from the sale of stamps and incurs costs in the operation of the programs. The revenue functions and the cost functions are discussed in turn.

The revenue function for stamps

The total revenue from the sale of stamps is represented by

$$(1)\quad TR_s = \sum_i P_i p_{si} \bar{q}_{si} \qquad (i = 1, \cdots, N)$$

where:

- $i = 1, \cdots, N$ household classes. The program operates with both household size and income classes, which have been collapsed here for notational simplicity;
- P_i = number of participants in the ith household class of eligible households;
- p_{si} = price per food stamp charged to eligible households in class i;
- $\bar{q}_{si}$ = quantity of food stamps eligible households in class i must purchase if they are to participate.

The price and quantity of food stamps are derived as follows: To participate in the program, an eligible household expends a specified amount of cash called its "purchase requirement" on food coupons and in return receives a specified number of coupons called its "coupon allotment."[3]

If a food stamp is defined as the quantity of coupons worth one dollar in terms of food, then $p_{si}\bar{q}_{si}$ = the purchase requirement, $\bar{q}_{si}$ = coupon allotment, and p_{si} = purchase requirement/coupon allotment. The purchase requirement is a positive function of household income within any household size class, and the coupon allotment is a positive function of household size.[4]

The participation in the ith class, P_i, is the aggregate demand to participate in the program of households in the ith class.[5] It depends upon the demand for food on the part of eligible households in the ith class, the price charged them for food stamps, and the quantity of food stamps they are required to buy if they are to participate. For instance, given a *ceteris paribus* increase in the price of food stamps, fewer households will find that participation in the program benefits them (if food is a normal good), and hence participation, P_i, will decline. Moreover, note that if p_{si} = \$1.00, then there is no benefit from participating and there is no demand. If the price is zero, food stamps would be a free good and all those eligible would participate, *ceteris paribus*. In consequence, $0 \leq p_{si} < 1$.

Appropriations revenue function

Congress imposes two sorts of constraints on the behavior of the FNS. The first is the legislation authorizing the program plus all of its amendments along with informal directives given to the bureau in the context of bargaining at appropriations time. The second constraint is the appropriations. We are here concerned with the appropriations constraint.

Congress is viewed as being faced with budget requests for a myriad of programs each year among which its limited resources must be allocated and as having preferences with respect to the program level of each program. With respect to the FSP, it is willing to allocate additional funds to expand the program from a low

[3] As a result of the 1971 amendments (P.L. 91-671) eligible households may now purchase less than the maximum coupon allotment. This regulation does not affect the empirical base of this study.

[4] Until 1970 [15] both the purchase requirement and the coupon allotment were functions of household size and income.

[5] The demand to participate in the program is derived in [2].

Table 1. Summary of federal costs and participation in Food Stamp Program, fiscal 1968–71

	1968	1969	1970***	1971***
	dollars			
Value of bonus coupons	173,116,687*	228,788,020	550,874,720	1,523,055,857
Certification	4,358,783	6,981,000	9,392,089	20,200,000
Destruction	66,000	88,000	105,000	226,000
Printing	1,411,571	4,671,668	4,262,824	15,369,811
Transportation	34,072	58,720	72,600	255,189
Administrative	8,296,702**	10,394,485	13,336,048	17,830,938
Total	187,283,815	250,981,893	578,043,281	1,576,937,795
	persons			
Average monthly participation	2,211,224	2,878,113	4,340,030	9,382,089

* Includes $2,487,679 funded by OEO.
** Includes $47,203 funded by OEO.
*** Obligations, not costs.
Source: FNS-USDA [14].

program level. At higher program levels it is willing to allocate *fewer* funds in return for the *same amount* of program expansion. It is debatable whether there exists a situation in which appropriations are lowered if the program is expanded.

Program level, of course, depends upon the aspect of the program that is judged to be important by Congress and that judgment changes from time to time as the political environment changes. Three aspects of the program have been important historically: the total number of stamps distributed ($Q_s = \sum_i P_i \bar{q}_{si}$), the aggregate number of participants ($\sum_i P_i$), and whether a participating household can afford to purchase a nutritionally adequate diet. It is assumed in this analysis that the maximum appropriation Congress is willing to grant the FNS to operate the FSP (TR_a) is a function of Q_s and of $\sum_i P_i$;[6] i.e.,

$$(2)\quad TR_a = a(w_s Q_s, w_p \sum_i P_i) \quad (i = 1, \cdots, N)$$

where w_s and w_p are weights indicating the importance Congress attaches to the total quantity of stamps distributed and to aggregate participation, respectively, as aspects of program level. Of course, $w_s + w_p = 1$. Further,

$$\partial a/\partial w_s Q_s = a_s \geq 0; \quad \partial a_s/\partial w_s Q_s \leq 0;$$
$$\partial a/\partial w_p \sum P_i = a_p \geq 0; \quad \partial a_p/\partial w_p \sum P_i \leq 0.$$

The total cost function

While the FNS administers several other programs in addition to the FSP, it is only the costs incurred by the agency attributable to the FSP that are of interest.[7] As in any economic analysis it is the minimum cost for each program level that is of interest.

The FNS reports the costs of the FSP under the following heads: administration, stamp printing and destruction, certification, transportation, and the value of bonus coupons. Table 1 shows the breakdown of costs for recent years. Stamp printing and destruction costs clearly are a positive function of the number of stamps distributed. So also are certification costs, since they are related via the number of households certified and thus via participation. Undoubtedly, some portion of administrative and transportation costs is also some positive function of the quantity of stamps distributed.

The value of bonus coupons equals the market value of the stamps in terms of food minus the revenue from the sale of stamps. It represents the total transfer payment made to participating households. The market value of the stamps is treated as a charge against the cost of the program, while the revenue from the sale of stamps can be treated as either a dele-

[6] This is a variant of a function suggested to me by William Niskanen in comments on an earlier draft. It differs from the "budget-output functions" in [10, pp. 24–30] only in that it recognizes that the FSP has a number of politically important facets. Ensuring that participants could afford nutritionally adequate diets simply involves guaranteeing that $\bar{q}_{si}$ is set at a level determined to be adequate by nutritionists. Since the implications of raising $\bar{q}_{si}$ to such a level (as occurred in late 1969) are relatively simple to trace, this facet of the program was excluded from the formal analysis.

[7] The formal model regards the FNS as if it operated only one program and thus ignores the interrelations between the costs of the FDP and the costs of the FSP. Their costs are interrelated because they are competing programs in the sense that only one can be operated in any area. Thus, a local welfare district that switches from the FDP to the FSP alters the costs of both programs. This complication is not essential to the analysis.

tion from costs or an addition to revenue received by the agency even though the Treasury is the actual recipient. It is treated as an addition to agency revenue in this analysis, implying that the marginal cost of stamps is equal to $1.00 plus the marginal administrative, stamp printing and destruction, certification, and transportation costs. Define TC as the total minimum cost attributable to the FSP and,

$$TC = c(Q_s), \tag{3}$$

where $\partial c/\partial Q_s = c_s > 1$ and $\partial c_s/\partial Q_s \geq 0$.

Agency objective functions

A main tenet of this paper is that the FNS administers the FSP so as to achieve its own objectives, whatever other objectives it might seek to achieve. In this we agree with Niskanen [9, pp. 293–294] who states,

> Among the several variables that may enter the bureaucrat's utility function are the following: salary, perquisites of the office, public reputation, power, patronage, ease of managing the bureau, and ease of making changes. All of these variables, I contend, are a positive monotonic function of the total budget of the bureau.

If this is true, then it is analytically useful to regard bureaus in general and the FNS in particular as maximizing their total revenue subject to total cost in pursuit of their objectives. In essence, the FNS is regarded as a revenue-maximizing monopolist in the peculiar but not uncommon position of selling its output simultaneously to Congress and to participants in the program.

The FNS can, however, pursue its objectives in two ways. On the one hand it can pursue its own goals without regard for the intent of Congress except as it is revealed through the appropriations revenue function. This view is identical to that portrayed and analyzed by Niskanen [9, 10]. On the other hand the FNS can pursue its own objectives at the same time that it cooperates with Congress in attempting to maximize the aspects of the program which Congress deems important.[8] Since some of the empirical implications of these two views differ substantially, both are pursued. For brevity the bureau which pursues only its own goals will be called a ***budget-maximizing bureau*** to be consistent with Niskanen's terminology. The bureau which pursues its own goals in addition to those of Congress will be called a ***modified budget-maximizing bureau.***

The objective function of the ***budget-maximizing bureau*** can be expressed as

maximize TR subject to

$$TR \geq TC, \tag{4}$$

where $TR = TR_a + TR_s$

While changes in the importance Congress places on different facets of the program alter TR_a through changes in w_s and w_p, the basic form of the objective function does not change through time.

Such is not the case with the objective function of the ***modified budget-maximizing bureau,*** which changes only when Congress changes what it deems important. Specifically, from the program's inception in fiscal 1964 (it existed as a pilot program from 1961) through 1968 when hunger and malnutrition became politically important [7], the FSP was conceived and run as a device to support farm income. As such, the total quantity of stamps distributed was of paramount importance because Q_s sets the lower bound on the food expenditures of participants and gross farm income is an increasing function of food expenditures. For the period 1964 to perhaps 1968 and probably until late 1969, the objective function of a ***modified budget-maximizing bureau*** can be expressed as

$$\sum_i P_i \bar{q}_{si} + \lambda^f [TC - TR],\text{[9,10]} \tag{5}$$

where $\lambda^f < 0$.

After hunger and malnutrition became politically important, however, the FSP was increasingly viewed as an in-kind welfare program in which aggregate participation was the facet of importance. By the end of 1969 this objective was probably paramount. For the period from 1969 to date, the objective function can then be expressed as

$$\sum_i P_i + \lambda^p [TC - TR], \tag{6}$$

where $\lambda^p < 0$.

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[8] I am indebted to William Niskanen for pointing this distinction out to me.

[9] I am indebted to Martin Abel for suggestions leading to this particular way of formulating the problem of maximizing gross farm income with the program.

[10] For the use of a similar analytical technique in examining the employment behavior of a nonprofit agency subject to constraints on the amount of labor it can use, see [3].

Implicit in both equations (5) and (6) is the assumption that the FNS has been cost constrained throughout its history; i.e., the FNS has never operated such that $TR > TC$. The presentations of the agency before appropriations hearings appears to bear this out: the FNS has never argued for the same or smaller appropriations for the FSP than it had the previous year. A strong implication of this assumption, however, is that the FSP has been run efficiently. Such an assumption is dubious.

Price, Output, and Participation Implications

The implications of budget-maximizing and modified budget-maximizing behavior along with the alterations in the program brought about by the politics of hunger in America can be used to deduce a variety of implications about the price, participation, and output behavior of the FNS in its conduct of the FSP. In this paper we draw only those implications which can be used to distinguish between the two models of bureaus postulated and to explain the major price, participation, and output fluctuations that have occurred over the program's history. These hypotheses and the evidence relevant to them follow.

Price implications

Price policies consistent with the objectives of the two types of bureaus are derived under two alternative assumptions about the importance placed by Congress on the total quantity of stamps distributed and aggregate participation. For the period 1964 to 1968 it is assumed that the total quantity of stamps was the program characteristic of primary importance to Congress and, therefore, $w_s = 1$ and $w_p = 0$ in the appropriations revenue function. For the period 1969 to date it is assumed that the program facet of paramount importance has been aggregate participation and, thus, $w_s = 0$ and $w_p = 1$.

The *budget-maximizing bureau* practices perfect price discrimination among household groups in order to ensure that total revenue is a maximum at each possible level of Q_s and P_i. The pricing policy consistent with this objective differs according as Q_s or $\sum P_i$ is viewed as paramount to Congress. For the period 1964 to 1968 when the FSP was regarded as a farm income support program the price policy would be

$$(4.1)\quad p_{si} = \frac{\lambda_s - a_s}{(1 - 1/\beta_i)} \quad (i = 1, \cdots, N)$$

for each level of Q_s,[11]

where:

$\lambda_s \geq 0$ = total marginal revenue with respect to Q_s,

a_s = marginal revenue of appropriations with respect to Q_s,

β_i = absolute value of the price (p_{si}) elasticity of the demand to participate in the FSP on the part of households in class i. Given that the opportunity cost of expenditures on stamps is high for all poor people, it is assumed that $\beta_i > 1$.

For the period 1969 to date when the program has been viewed as a welfare program, the price policy would be

$$(4.2)\quad p_{si} = \frac{\lambda_p - a_p}{\bar{q}_{si}(1 - 1/\beta_i)} \quad (i = 1, \cdots, N)$$

for each level of $\sum P_i$,[11]

where:

$\lambda_p \geq 0$ = total marginal revenue with respect to $\sum P_i$,

a_p = marginal revenue of appropriations with respect to $\sum P_i$.

The price policies of the *modified budget-maximizing bureau* flow directly from the first order conditions of equations (5) and (6). For the period 1964 to 1968 the price policy would be

$$(5.1)\quad p_{si} = \frac{c_s - a_s}{(1 - 1/\beta_i)} + \frac{1}{\lambda'(1 - 1/\beta_1)} \quad (i = 1, \cdots, N)$$

where c_s is the global marginal cost of increasing Q_s by one stamp. For the period 1969 to date the price policy of such a bureau would be

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[11] Equations (4.1) and (4.2) are obtained by maximizing

$$(4.3)\quad a(w_s Q_s, w_p \textstyle\sum P_i) + \lambda_s[w_s(K_s - Q_s)] + \lambda_p[w_p(K_p - \sum P_i)]$$

with respect to P_i (or p_{si} since the same result obtains) where K_p and K_s are constants. To derive (4.1) from (4.3) set $w_s = 1$ and $w_p = 0$. To derive (4.2) from (4.3) set $w_s = 0$ and $w_p = 1$.

Table 2. Average prices per stamp charged participants in Food Stamp Program by per capita household income and size of household; 1964, 1969, and 1971

Income per capita per month	1964				1969				1971			
	number of persons per household											
	1	2	3	4	1	2	3	4	1	2	3	4
0–19	.29	.28	.31	.31	.02	.03	.06	.07	0	.03	.05	.07
20–29	.50	.49	.53	.55	.04	.20	.19	.22	.03	.15	.19	.22
30–39	.56	.57	.63	.64	.14	.30	.29	.34	.13	.23	.27	.33
40–49	.60	.64	.71	.70	.21	.40	.39	.45	.19	.33	.38	.44
50–59	.64	.67	.76	.75	.29	.49	.51	.57	.25	.41	.49	.55
60–69	.73	.75	.79	.77	.36	.55	.58	.66	.31	.50	.56	.66
70–79	.73	.72	.80	.77	.43	.64	.73	.72	.38	.59	.70	.77
80–89	.73	.77	.80	.78	.50	.64	.78	.75	.44	.65	.77	.85
90–99					.57	.64	.79	.77	.50	.75	.88	.92
100–109					.64	.64	.79	.77	.56	.85	.90	

Source: Computed from Basis of Issuance Tables for Feb. 1964 (Northern Issue), Dec. 1969, and July 1971; FNS-USDA [14].

Tables are truncated in that the source tables give prices for households up to 8 persons and for higher income per capita income classes in later years.

$$p_{si} = \frac{c_s}{(1 - 1/\beta_i)} - \frac{a_p}{\bar{q}_{si}(1 - 1/\beta_i)} + \frac{1}{\lambda^p \bar{q}_{si}(1 - 1/\beta_i)} \quad (i = 1, \cdots, N). \tag{6.1}$$

These pricing policies can be compared with each other and with the pricing policies of the FNS in the two periods. The comparisons are made to determine which model of a bureau most closely fits the behavior of the FNS. The comparisons are based on one assumption and one fact. The assumption is that the demand to participate in the FSP is more price elastic for households with low per capita household income than for those with high per capita household income. This appears reasonable, given that the opportunity cost of expenditures on stamps probably declines as per capita income rises. The fact is that the quantity of stamps households have been required to purchase has throughout the life of the FSP been an increasing function of household size.

Now compare equations (4.1) and (5.1). Price discrimination is clear in both equations. Either type of bureau would charge high prices to households with high per capita income and low prices to households with low per capita income. The left-hand part of Table 2 shows average prices charged in 1964 to households of different per capita household income and household size classes. The prices for 1964 in Table 2 were derived from the northern price and quantity "lists" by household income and size issued by the FNS to local welfare departments in February 1964. The prices for 1964 are consistent with either model postulated as representative of FNS behavior.

A comparison of equations (4.2) and (6.1) yields the same condition. Within any household size category (and therefore holding $\bar{q}_{si}$ constant) either type of bureau would charge lower prices to poor households than to the not-so-poor. The price and quantity lists issued by the FNS in December 1969 and again in July 1971, from which the 1969 and 1971 prices in Table 2 were computed, reveal this type of price discrimination. Again, on this evidence alone there is no basis for deciding which model most closely represents FNS behavior.

Now note that price is independent of $\bar{q}_{si}$ in equations (4.1) and (5.1), whereas price is dependent on $\bar{q}_{si}$ in both equations (4.2) and (6.1). Moreover, in equation (4.2) p_{si} is negatively related to $\bar{q}_{si}$, whereas in equation (6.1) p_{si} is positively related to $\bar{q}_{si}$. Since $\bar{q}_{si}$ is a positive function of household size, a comparison of the relationship between price and household size, holding income per capita (and therefore β_i) constant can distinguish between the models postulated.

In 1964 within any income per capita class prices charged households of a given size averaged \$.02 more than prices charged households of the next smaller size. The analogous average was \$.06 for 1969 and \$.11 for 1971. In other words, as time passed a *positive* relationship between prices charged and household size, holding per capita income constant, has emerged. This result is consistent with the notion that the FNS has behaved like a ***modified budget-maximizing bureau***. The slight positive relationship that exists in the 1964 price structure can

be explained either on the grounds of random error or on the basis that even in 1946 aggregate participation was not deemed of no political importance by Congress. These relationships clearly contradict the notion that the FNS has behaved as a *budget-maximizing bureau.* In what follows the model of the *budget-maximizing bureau* will be dropped in favor of the model of the *modified budget-maximizing bureau.*

The history of changes in the price structure shows that the relationship between per capita household income and the price of stamps has only been strengthened by succeeding changes. In 1968 the prices charged the poorest of the poor were lowered after intense fire was directed at the FNS in hearings by the Subcommittee on Employment, Manpower, and Poverty of the Senate Committee on Labor and Public Welfare in 1967 and 1968 [18]. The entire price structure was lowered by an average of 30 percent in December 1969 [15]. Changes as a result of the 1971 amendments to the Food Stamp Act (P.L. 91-671) that are being made currently drop prices for the poorest of the poor to zero and raise prices to the least of the poor. The former is in recognition of the fact that some of the poorest households have little or no cash income, while the latter change is an effort to diminish the "notch" implicit in the old price structure [17].

Output and participation implications

There are several hypotheses that can be tested with respect to the output and participation implications of the models. One concerns the relationship between participation in the FSP and participation in the FDP (Food Distribution Program), the other program administered by the FNS which directly competes with the FSP. Another set of hypotheses has to do with the time pattern of FSP participation and output and the changes in them brought about by the politics of hunger. Each is dealt with in turn.

It has been noted that for the purposes of analysis the FNS can be regarded as a three-program bureau: the FSP, the FDP, and all other programs it operates. The FSP is financed by annual appropriations authorized under the Food Stamp Act of 1964 as amended. There is no such specific legislative authorization for the FDP. Instead, it is operated with funds authorized under Section 32 of P.L. 74-320 which annually allocates 30 percent of customs receipts to the USDA to be used in a variety of unspecified ways to support farm income. These funds are not subject to the annual appropriations process and are not dependent upon the level at which the FDP is operated. The FNS receives the funds regardless of whether the FDP exists.[12] It is important to realize that the FSP and the FDP perform the same function—one sells food stamps to the poor while the other gives food away—and legally are substitutes for each other; that is, both subsidize the food expenditures of low-income families and legally the two cannot be operated simultaneously in the same local welfare district.

These circumstances provide a revenue-maximizing bureau with the opportunity of substituting one program (the appropriations for which are dependent on program level) for the other program (the funding for which is independent of output). This permits the use of funds so released to be used elsewhere. If this is the case, then through time one would observe participation in the FDP to fall as participation in the FSP rose, *ceteris paribus.*

A test of this hypothesis is provided by regressing participation in the FDP by month from July 1963 to June 1971 (X_1) [14] on participation in the FSP (X_2) [14] and the seasonally unadjusted civilian unemployment rate expressed as a percent (X_3) [16]. The latter is included to hold constant the hypothesized positive relationship between participation and the unemployment rate. The seasonally unadjusted rate is used to capture seasonal variation in participation resulting from seasonal fluctuations in unemployment. The results are as follows:

$$(7)\quad \hat{X}_1 = 1{,}699{,}792.80 - \underset{(-12.67)}{.20094832X_2} + \underset{(12.50)}{682{,}366{,}49X_3}$$

$$\bar{R}^2 = .6886 \quad \text{number of observations} = 96.$$

The numbers in parentheses are t-ratios. The effects of both variables are significantly different from zero and consistent with expectations.

The second set of hypotheses arises from the politics of hunger and malnutrition in America. This issue was politically explosive, beginning

[12] In fact, the Consumer and Marketing Service receives Section 32 funds to purchase the commodities and the FNS receives Section 32 funds to process and distribute them. Congress from time to time does put restrictions on the use to which Section 32 funds can be put. For instance, P.L. 90–91 prohibits Section 32 funds from being used in the FSP.

in April 1967 as the result of hearings in Mississippi of the Senate Subcommittee on Employment, Manpower, and Poverty [18]. Thereafter, evidence piled up rapidly of malnutrition among the poor, deficiencies in federal food aid programs, especially the FSP and the FDP, and of discriminatory administration of the programs at the local level. (See, for instance [5, 6, 7, 12, 13].) The relevant issues here included: benefits under the FSP did not ensure that recipients could afford a nutritionally adequate diet; many of the poor could not afford to participate in the program; and there were many local welfare districts in the country that offered neither the FDP nor the FSP.

The growing involvement in Southeast Asia and foot-dragging by the Agriculture Committees in Congress created much competition for funds and kept appropriations from growing as quickly as they might have otherwise. Appropriations for the FSP grew by $45 million in fiscal 1968 and by $40 million in fiscal 1969. As pressure grew, however, FSP appropriations jumped by $525 million for fiscal 1970 and by $500 for fiscal 1971.[13]

Such increases in revenue from appropriations can affect prices and output in two ways. If the program does not have nationwide coverage, efforts are made to open projects in counties not offering either program, that is, to expand the number of eligible households. There is also a tendency to lower prices.[14] Furthermore, as the public and Congress increasingly adopted the view that the FSP should ensure that recipients could afford a nutritionally adequate diet, there was pressure to increase the quantity of stamps households were required to purchase in order to participate. In the absence of increased revenue from appropriations and given the pressure to increase participation, such a move alone would have forced food stamp prices down. This is so because a *ceteris paribus* increase in the quantity of stamps required would have lowered participation [2, p. 17] and prices would have been lowered to offset the decline.

In sum, then, it is hypothesized that the effects of the politics of hunger were to shift the revenue from the appropriations curve upward and to increase the quantity of stamps recipients had to buy. The implications of these actions were to increase participation via program expansion and to lower food stamp prices, both of which increased participation. While the program was slowly expanded into new areas in fiscal 1968 and 1969 (189 new projects in fiscal 1968 and 462 in 1969 [14]), prices and quantities did not change until mid-fiscal 1970, the first year in which appropriations greatly increased.

To estimate the effects on participation and output, two regressions were run. First, participation in the FSP by month from July 1963 to June 1971 (X_2) was regressed on the seasonally unadjusted civilian unemployment rate (X_3), the number of FSP projects in operation (X_4),[15] and a dummy variable taking on the value zero for each month from July 1963 through January 1970 and taking on the value one thereafter (X_5). Second, the total quantity of stamps distributed per month from July 1963 to June 1971 (X_6) was regressed on the same independent variables. The districts offering the program were measured by the number of FSP projects in operation and so also was the geographic expansion of the program. The dummy variable captured the effect of the simultaneous change in price and quantities. Prices were lowered from a weighted average of $.62/stamp to $.43/stamp, whereas the weighted average required quantity per person per month was raised from $17 to $24 in an announcement on December 18, 1969 [15]. Implementation of the change was not widespread until February, 1970.[16]

The results are as follows:

$$(8)\quad \begin{aligned}\hat{X}_2 = &- 1{,}949{,}242. + \underset{(4.26)}{463{,}395.70X_3} \\ &+ \underset{(14.71)}{2{,}632.528X_4} + \underset{(7.26)}{2{,}742{,}656.9X_5}\\ \bar{R}^2 = &\ .9399 \quad \text{No. of observations} = 96.\end{aligned}$$

[13] These figures come from various agriculture appropriations bills: P.L. 89-556 for 1967; HR-10509 for 1968; HR-16913 for 1969; P.L. 91-127 for 1970; and, HR-17923 for 1971.

[14] The effect of an exogenous change in revenue from appropriations can be shown by differentiating (6.1) with respect to a_p, the marginal revenue from appropriations. This yields:

$$(6.2)\quad \partial p_{si}/\partial a_s = - 1/(\bar{q}_{si}(1 - 1/\beta_i)) \gtrless 0 \text{ as } \beta_i \lessgtr 1 \quad \text{for all } i = 1, \cdots, N.$$

[15] A project is a county, city, or an Indian reservation which operates a FSP program independently of other local units [14].

[16] Thirty-two states implemented the program changes in January and February, 1970. Ten more states implemented the changes in March and another state was added to the list in April. February was chosen as the date at which implementation was widespread.

$$(9) \quad \hat{X}_6 = -56{,}455{,}627. + \underset{(4.55)}{12{,}484{,}881.X_3} + \underset{(11.60)}{52{,}327.271X_4} + \underset{(9.22)}{87{,}776{,}702X_5}$$

$\bar{R}^2 = .9368$ No. of observations = 96.

The figures in parentheses are t-ratios. Each of the coefficients in the two equations is significantly different from zero and each is consistent with expectations. Expanding the program geographically by one project adds 2,632 participants and increases output by 52,327 stamps. An increase in the unemployment rate by one-tenth of a percentage point increases participation by 46,339 and output by 1.2 million stamps. The combined price and quantity changes increased participation by 2.7 million and output by 87.8 million stamps. Increasing unemployment, geographic expansion of the program, and the abrupt liberalization of the program halfway through fiscal 1970, therefore, adequately account for the 50 percent jump in participation in fiscal 1970 and the 16 percent increase in fiscal 1971 [14].

Finally, from an examination of the residuals it appears that there was no more than a three-month lag between the time implementation of the liberalization was widespread and the time the response to it was completed. This is a very rapid response by any standard especially since 11 states did not implement the change until March and April. It is especially impressive in light of the fact that lack of knowledge about the program was given as the primary reason for establishing in 1968 an outreach program in which the poor were employed by the USDA, trained as nutrition aides, and sent out into the community to inform needy households about the program [18]. This casts doubt on the belief that lack of knowledge about the program was an important reason for lack of program participation. Rather, it supports the view that until the program was liberalized, it was not worthwhile for many of the poor to participate. This view is buttressed by Steiner's observation [13, p. 215] that participation in food programs dropped by more than 50 percent when the FDP was replaced by the FSP at the end of fiscal 1967.

Summary and Conclusions

Two models of bureaus were built in which one postulated that the FNS was a revenue-maximizing, price-discriminating monopolist, while the other postulated that the FNS maximized revenue while it actively pursued the intent of Congress as well. The former model was rejected in favor of the latter. The test used to reject the former model was rough and not tightly controlled, and thus the author regards the rejection as tentative, to be supported or refuted by other evidence. If it happens, however, that other tests support a characterization of the FNS as a bureau actively cooperating with the relevant Congressional committees, it will be consistent with the impression one receives from the various historical treatments of the FSP [7; 12; 13, Chap. 6]. It appears that the House Appropriations Committee, Subcommittee on Agriculture, has had an uncommon influence over the conduct of the FSP. This is in contrast with the impression this author has of relations between Congress and other federal bureaus. Clearly, the model of a *budget-maximizing bureau* which does not pursue the intent of the relevant Congressional committees except as it appears in the appropriations revenue function appears to fit some other federal agencies more closely. Obviously, additional research on these matters is needed.

How important is this effort? The fact that the model has not been rejected out of hand makes the author more hopeful that it might have some predictive as well as explanatory power. Had the model been rejected as an explanation of the price and output behavior in the food stamp market, doubt would have been cast on the efficacy of similar models of other public sector markets. And, if the model had no empirical content, then it would not be suitable as a wheel on which to spin normative theories. The fact that it was *not* rejected gives a little more credence above that lent by intuition alone to the kind of work Niskanen has been about in the normative sections of his recent book [10]. Much more work needs to be done, however, on the demand side of such models before they can serve as convincing guides for policy making.

References

[1] BRYANT, W. KEITH, "Allocative Mechanisms in Public Markets: A Neoclassical Fantasy," manuscript prepared for discussion at the final meeting of NCR-77, Chicago, Ill., Dec. 1970.

[2] ———, "Participant Demand Functions for In-kind Transfer Payments," Discussion paper No. 96-71, Institute for Research on Poverty, Univ. Wisconsin, Madison, June 1971.

[3] CARLSSON, R. J., J. W. ROBINSON, AND J. M. RYAN, "An Optimization Model for a 'Nonprofit' Agency," *West. Econ. J.* 9:78–86, March 1971.

[4] HOOVER, DALE M., AND J. G. MADDOX, *Food for the Hungry: Direct Distribution and Food Stamp Programs for Low-income Families*, National Planning Association Planning Pamphlet No. 126, Feb. 1969.

[5] *Hungry Children*, Special report of the Southern Regional Council, Atlanta, Ga., 1967.

[6] *Hunger, U.S.A.*, A report of the Citizen's Board of Inquiry into Hunger and Malnutrition in the U.S., Washington, New Community Press, 1968.

[7] KOTZ, NICK, *Let Them Eat Promises: The Politics of Hunger in America*, Englewood Cliffs, N.J., Prentice-Hall, Inc., 1969.

[8] NELSON, PAUL E., JR., "Michigan Food Stamp Program: A Partial Analysis of Performance," *Am. J. Agr. Econ.* 54:51–59, Feb. 1972.

[9] NISKANEN, WILLIAM A., JR., "The Peculiar Economics of the Bureaucracy," *Am. Econ. Rev.* 58:233–305, May 1968.

[10] ———, *Bureaucracy and Representative Government*, Chicago, Aldine-Atherton, 1971.

[11] PAARLBERG, DON, *Subsidized Food Consumption*, American Enterprise Institute for Public Policy Research, Washington, May 1963.

[12] SEGAL, JUDITH A., *Food for the Hungry: The Reluctant Society*, Baltimore, Johns Hopkins Press, 1970.

[13] STEINER, GILBERT Y., *The State of Welfare*, Washington, The Brookings Institution, 1971.

[14] U.S. Department of Agriculture, *Food and Nutrition Service Fiscal Year 1969 Statistics and Historical Tables*, FNS/Program Reporting Staff-USDA, Oct. 1970 (extension of data through 1971 supplied by FNS).

[15] ———, "Secretary Hardin Announces Details of Big Food Stamp Program Expansion," USDA Press Release No. 3873-69, Washington, Dec. 18, 1969.

[16] U.S. Department of Commerce, Office of Business Economics, *Survey of Current Business*, various issues.

[17] U.S. Senate, H.R. 16311, *The Family Assistance Act of 1970*. Revised and Resubmitted to the Committee on Finance by the Administration, 91st Cong., 2nd sess., June 1970.

[18] ———, Hearings before the Subcommittee on Employment, Manpower, and Poverty of the Committee on Labor and Public Welfare, 90th Cong., 1st sess. on Hunger and Malnutrition in America, July 1967; 90th sess. on Senate Resolution 281, June 1968.

Theory of the Firm and The Management of Residuals*

Max R. Langham

The neoclassical theory of the firm assumes that a producer is a profit maximizer in an environment consisting of a bundle of fixed resources, a production function, supply functions for inputs, and demand functions for outputs. Given this environment the theory explains the producer's behavior with regard to his demand for inputs and his supply of goods and services.

In the first two parts of this paper, producer behavior is examined under conditions in which society imposes additional requirements on the producer in its attempt to manage residuals.[1] As in neoclassical theory, it is assumed that the decision maker knows the technical transformation which creates the residuals of concern to society and that society's signals to the producer regarding pollution are well defined—perhaps as functions. This latter information may be in the form of taxes or restrictions on residuals. The results of these two sections come back like a familiar melody played by a short-run static model at the micro level.

These results of course do not mean that all is well with neoclassical firm theory but rather that the assumption of perfect knowledge is just more "heroic" and untenable when residuals management enters the decisions faced by the firm. Partial relief for the added stress which residuals management places on firm theory may be obtained by added developments in probabilistic microeconomic theory.[2] In this direction the third part of the paper introduces institutional risk and briefly explores the implications of this risk on output and residuals production.

Consideration of residuals in decision models can lead to added problems of nonconvexities in the set of feasible alternatives. As a consequence, there is danger of finding only the nth best solution at some local optima or perhaps worse. Problems with nonconvexities are considered briefly in the fourth section.

A concluding section touches on problems of jargon and data.

Residuals as a Fixed Proportion of Output

For purposes of simplification the discussion in this and the next three sections assumes[3] one product (y_1), one residual (y_2),[4] two variable inputs (x_1) and (x_2), and fixed prices.

Case 1: a tax on the residual

If the residual is created in fixed proportions with output, a tax levied against the residual shows up simply as a reduction in output, but the conditions on the firm's expansion path are unaffected, i.e., in this simplified case the first order conditions remain

$$\frac{f_1}{f_2} = \frac{p_{x_1}}{p_{x_2}}. \tag{1}$$

Case 2: a constraint on the level of the residual

A fixed restraint on the level of the residual, $y_2 \leq y_2^*$, will simply constrain output to a fixed proportion, b, of the constraint on the residual. Again, the conditions on the firm's expansion path will remain unchanged over the range of feasible outputs, i.e., over the range $0 \leq y_1 \leq by_2^*$.

It is clear that the firm's optimal level of output in this case may be $\gtrless$ that for case 1. And, there is a level of restriction on y_2 which will equate the solution for both cases.

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[1] In this paper the term residuals is used to refer to wastes jointly forthcoming from the production process. Concern is with those waste outputs which are damaging to the environment.

[2] For a timely survey article on probabilistic microeconomics see McCall [7].

[3] The discussion also assumes that the set of feasible solutions is a closed convex set and that $y=f(x_1, x_2)$ is strictly concave over the feasible set. Detailed derivations of the necessary first order conditions on the expansion path are not presented since they are generally familiar.

[4] Like any output of the production process, a residual can of course be treated as a negative input. The choice is arbitrary as will be seen later.

Max R. Langham *is professor of food and resource economics at the University of Florida.*

Residuals as a Function of Some Subset of Inputs[5]

Case 1: a tax on the residual

Assume that only x_1 creates a residual problem and that y_1 and y_2 are determined by the model:[6]

$$
(2)\quad
\begin{aligned}
&\text{(i)} && \max \pi = p_1y_1 - p_{x_1}x_1 - p_{x_2}x_2 - Ty_2 \\
& && \text{s.t.} \\
&\text{(ii)} && y_1 = f(x_1, x_2) \\
&\text{(iii)} && y_2 = g(x_1) \\
&\text{(iv)} && x_1, x_2, y_1, y_2 \geq 0.
\end{aligned}
$$

The residual y_2 may be thought of as a product with a price equal to minus the tax rate, T, or as an input with price T. In either case the condition of the firm's expansion path is

$$
(3)\qquad \frac{f_1}{f_2} = \frac{p_{x_1} + Tg_1}{p_{x_2}}.
$$

The result is that the marginal unit cost of the input, x_1, is increased by the marginal factor cost of the residual. And, the imposition of the tax T will lead to less use of x_1 and/or greater use of x_2.

Case 2: a constraint on the level of the residual

Now the firm's optimization process is subject to a maximum residual constraint and the model is as follows:

$$
(4)\quad
\begin{aligned}
&\text{(i)} && \max \pi = p_1y_1 - p_{x_1}x_1 - p_{x_2}x_2 \\
& && \text{s.t.} \\
&\text{(ii)} && y_1 = f(x_1, x_2) \\
&\text{(iii)} && y_2 = g(x_1) \leq k \\
&\text{(iv)} && y_1, y_2, x_1, x_2 \geq 0.
\end{aligned}
$$

If for the optimal solution $g(x_1) < k$, the constraint is ineffective and the firm will be unaffected by society's residual constraint. If, however, the residual constraint is effective, the condition on the firm's expansion path becomes

$$
(5)\qquad \frac{f_1}{f_2} = \frac{p_{x_1} + \lambda g_1}{p_{x_2}}
$$

where $\lambda = 0$ if $g(x_1^*) < k$ and $\lambda \geq 0$ otherwise, x_1^* the optimal solution.

The numerator on the right-hand side of Equation 5 indicates the marginal unit cost of x_1 is increased by λg_1. The constraint again requires a reduction in the use of x_1 and/or a simultaneous increase in the use of x_2 if the constraint on the residuals is effective. If the constraint is not effective, the multiplier λ will be zero and as indicated above the firm will be unaffected in its decisions, that is, the firm will be satisfying the pollution constraint. When the level of the residual is fixed to the firm it becomes analogous to a fixed resource. Consequently, its shadow price is dear or cheap depending on the resource endowment in relation to demands on the resource.

A comparison of conditions (3) and (5) indicates the existence of a tax rate T and a constraint level k which will equate T and λ. As a consequence, there is a variable tax rate across firms which would be equivalent to fixing the residual level at k. Likewise, there is a residual level restriction, k_i, for the ith firm which would be equivalent[7] to a general tax T for each unit of the input levied against the producer.

One would normally expect the cost structure of firms to shift upward with the imposition of residual controls. If all firms were in long-run competitive equilibrium they would be able to survive new constraints on their productive enterprise only if the shift[8] in the product demand function of the firm was adequate to cover the shift in their average cost structure. If the shift in average revenue function of the firm does not permit the competitive firm to cover average cost after all adjustments to residual control, the firm will not survive. The ability to adjust may require that the firm be receiving some above normal profit prior to the imposition of residual control.

By varying k, model (4) can be used to express y_1 as a function of y_2. The result may be illustrated by curve OP in Figure 1. This function indicates the trade-offs between levels of product ("goods") and levels of residual ("bads"), given the current state of the arts, and can be interpreted much like a neoclassical production function. With knowledge of the relative prices society places on the bads and goods, the neoclassical theory of the firm pro-

[5] Use of commercial fertilizers and pesticides provides an example in agriculture.

[6] The first and second derivatives of $g(x_1)$, g_1, and g_{11}, are normally expected to be positive.

[7] Outputs and inputs would be the same but profits would differ.

[8] The shift would be brought about by a decrease in the industry's supply curve.

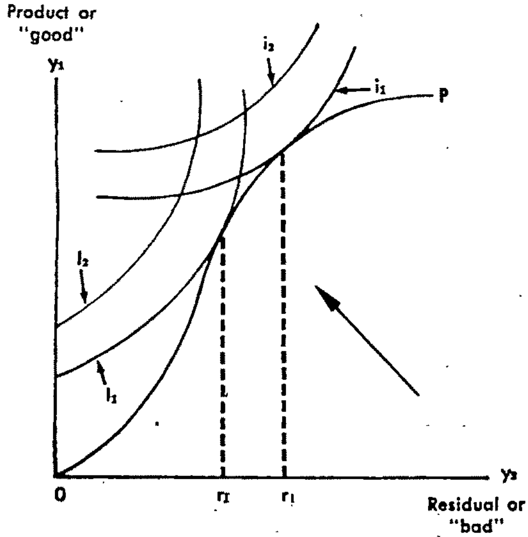

Figure 1

vides a useful framework for the decision problem.

The curve OP (Fig. 1) represents the trade-off function or production frontier between goods and bads. The more goods there are the more bads there are also. For a given level of the residual, the function represents the maximum attainable product. Alternatively, for a given level of product the function represents the minimum residual that must be forthcoming.

The model of Figure 1 can be generalized to the multi-product, multi-input, and multi-residuals cases. And, mathematical programming provides a well-known analytical tool. Trade-offs between goods and bads can be estimated parametrically by minimizing residuals for given levels of output or by maximizing output for given levels of residuals.

If society associates a risk with increasing levels of the "bad" and if society acts as a risk averter (i.e., the indifference curves are twice differentiable and $\partial y_1/\partial y_2 > 0$, $\partial^2 y_1/\partial y_2^2 > 0$), the community indifference curves will be like I_1 and I_2 with increasing utility in the direction of the arrow. However, the indifference curve between goods and bads for the individual producer may have greater or less slope than that for the community depending on his personal value system, and his curves may be increasing at an increasing or decreasing rate, i.e., $\partial y_1/\partial y_2 \geq 0$ and $\partial^2 y_1/\partial y_2^2 \gtrless 0$. One would expect, however, that the average firm polluting the commons would have indifference curves more like i_1 and i_2 since they would not have to bear the full cost of the residual.

The difference $(r_i - r_I)$ in the optimal levels of residuals from society's and the typical firm's points of view *for a given state of the arts* depends on the shape of the production frontier and that of the indifference curves. *For a given state of the arts* this difference is probably much less than many environmentalists would like to admit. Most of the dissatisfaction being aired is with the state of the arts in production processes.

Society can seek process change but much of the responsibility for adjustment falls on the micro unit. The need for adjustment in a poorly defined and immature institutional structure creates a great deal of uncertainty at the micro decision level.

Risks in Production

In neoclassical production theory the production function is defined to determine output precisely as a function of certain controlled variables with other variables held fixed. Similarly, it is assumed that the decision maker has perfect knowledge of supply functions for inputs and demand functions for products. Though such assumptions can help one gain specificity in the conclusions drawn from the theory, they are really not valid[9] in the real world where our knowledge is quite imperfect or can never be more specific than a probability distribution about some future phenomenon. As a consequence, there has been a great deal of activity in the profession to develop models which will accommodate risk. Two major recognized sources of risks in agriculture have been those associated with uncertain prices and those associated with uncertain outputs.

Risks, and particularly output risk, aggravate the problem of residuals management from society's point of view. One such aggravation, for example, is in the case where, attempting to guard against worst possible outcomes, the individual producer would use more of an input (say pesticides) than realistic expectations of insect infestation would justify. The individual would thereby lower his probability of crop failure due to insects but would add to society's risk from residuals. Such conflicts have been recognized [2, p. 97] and low cost insurance programs have been suggested as a means whereby society may reduce its own risks from

[9] There are several assumptions in the neoclassical theory of the firm that one might criticize as being invalid in the real world. For example, Georgescu-Roegen [5, p. 5] has indicated that the production function is in reality a functional rather than a function.

residuals by helping the individual producer lower his risk of failure.

Widespread public awareness of the environment has created added institutional risk[10] in production. This awareness appears to be leading into an era of "let the producer beware"—an era very much like that in an earlier period when the individual as a purchaser bore a similar risk. The risk arises because an individual, in this case the producer, must play his role by the rules of society. But society either does not know what its rules should be or is in the process of formulating them and does not have safeguards to protect the individual adequately in the current uncertain institutional framework.

Many agricultural producers today recognize a personal risk from institutional changes concerning residuals which will require either new production processes (a shift to a new production function) or perhaps even withdrawal from production. Even though producers follow what at the time seemingly are acceptable practices, there remains a real risk of public reaction to a new "crisis" created as a result of an institutional weakness.

Institutional risk as used here is the distribution of losses which the individual faces as a consequence of society's inability to establish an ex ante institutional framework for his decision-making process. To clarify this meaning let us consider the following example provided by an alleged real life story in Illinois.

> A farmer makes a sizeable investment in a cattle feedlot after having checked with local officials to make sure that he had satisfied local ordinances. After having assured himself that his plans were "proper" he began construction. During the final phases of construction a local paper editorialized against the feedlot on the issue of water pollution to a stream on the back side of the farm. Subsequent public pressure led to a restriction on the use of the facility.

This is a rather clear case of "let the producer beware" and one where local institutions failed the individual. Direct cost of the failure was borne entirely by the firm.

The impact of such risk on the behavior of the firm is similar to that of a tax on the firm's output, i.e., if the producer makes decisions on the basis of expected net returns.

To demonstrate, respecify the production function[11] in (4) as

$$y_{1i} = h(x_1, x_2, u_i), \tag{6}$$

where u_i is now a stochastic element in the production process created by the immature institutional framework. For simplicity assume that u_i takes on only two values 1 and 0 with probabilities q and $1-q$, respectively, and that the associated values of y are $f(x_1, x_2)$ and 0. That is, $y_{11}=h(x_1, x_2, 1)=f(x_1, x_2)$ and $y_{12}=h(x_1, x_2, 0)=0$.

This distribution indicates that society acting through its institutions permits production with probability q and places a ban on production with probability $(1-q)$.

Neoclassical firm theory would indicate that in a certain environment (u_i always one) the producer should use inputs and produce an amount such that

$$\frac{p_{x_1}}{f_1} = \frac{p_{x_2}}{f_2} = p_1.$$

However, if the producer makes decisions on the basis of expectations[12] in this new risk environment, he would use inputs up to the point where $\partial E(\pi)/\partial x_j=0$, $j=1$, 2—i.e., where[13] $p_{x_1}/f_1=p_{x_2}/f_2=p_1q$. The risk affects firm behavior much like a tax on output where the tax per unit of output is $p_1(1-q)$.

If the variance of net returns had no effect on the decision maker's utility function, he would be indifferent to producing with a known tax per unit of output of $p_1(1-q)$ and producing in an environment where he did not know the amount of the tax until after output was produced. However, one might expect that the producer's actions are affected by the variance of output as well as its expected level. If so, the institutional risk could have added effects on

[10] In the sense that little is known about outcomes, perhaps "uncertainty" would be a more appropriate term than "risk." However, I use the word "risk" here because of a later assumption that the distribution of outcomes is known—an assumption which is consistent with the perfect knowledge assumption of classical production theory.

[11] Zellner, Kmenta, and Drèze [9, p. 787] have specified a Cobb-Douglas production function with a random disturbance to represent such factors as "... weather, unpredictable variations in machine or labor performance, and so on."

[12] Zellner *et al.* [9, p. 787] were the first to my knowledge to assume that the decision maker would maximize the mathematical expectation of profit in conjunction with a stochastic production function.

[13] Here q acts in a capacity similar to a parameter introduced by Hoch [6] to permit firms in a sample to vary systematically from first order conditions due to institutional or other constraints.

production because the variance of output would also be increased—in this case by $[f(x_1, x_2)]^2 q(1-q)$.

Institutional change may affect the use of only one input or a subset of inputs. To illustrate this case the production function of (4) is defined as

$$y_{1i} = f(z_{1i}, x_2)$$

where

$$z_{1i} = x_1 - u_i$$
$$(7) \qquad u_i = k + v_i$$
$$Eu_i = k > 0.$$

Since $E(z_{1i}) < x_1$, $f[E(z_{1i}), x_2^*] < f(x_1, x_2^*)$. And, assuming f is concave and twice differentiable Jensen's inequality [7, p. 413] can be used to establish that $E[f(z_{1i}, x_2^*)] \leq f[E(z_{1i}), x_2^*]$. Therefore, $E[f(z_{1i}, x_2^*)] \leq f[(x_1-k), x_2^*] < f(x_1, x_2^*)$.

Since the production function is concave, the first order conditions for profit maximization with (7) as the production function implies that the first order condition when (4) is the production function would not be satisfied if the firm maximized expected profits.

$$\frac{\partial E[\pi(7)]}{\partial x_i} = 0 \Rightarrow \frac{\partial E[\pi(4)]}{\partial x_i} > 0$$

or that

$$\frac{p_{x_1}}{f_1} = \frac{p_{x_2}}{f_2} < p_1.$$

Again, in the face of such institutional risk the firm would systematically produce where marginal cost was less than marginal revenue. And, to the extent that firms feel risk associated with the institutional framework, they will tend to behave in a manner closer to a social optimum.

One would suspect that the expected value and variances of the distribution of losses associated with institutional risk could be decreased with greater knowledge of the political processes which establish the institutional framework. If so, institutional risk would have a considerable differential effect among producers, and the cost of institutional information would seem to encourage economies of size. Over time the presence of institutional risk may do more to increase firm size than to reduce the incidence of pollution. The net effect of this added risk could even be fewer decision units in agriculture and an increased pollution problem. However, such a result would not necessarily be expected since larger firms are quite visible and easier to identify as polluters. They are also thought to be more efficient in dealing with the technical aspects of the pollution problem.

With regard to investment decisions, institutional uncertainty would tend to shorten the decision maker's planning horizon. That is, for a given expected rate of return, the decision maker would want to recover invested capital in a shorter period so he would invest only if the expected net returns were greater than they would have to be in the absence of risk. The situation would be similar to investments in underdeveloped countries where institutional risk and uncertainties are major considerations.

In general, "optimal" solutions will tend to be more conservative when the economist admits stochastic elements into his theoretical model.[14]

Problems with Nonconvexities

New technology

The discussion thus far has assumed a given technology which specified the amount of residual as a fixed proportion of output or as some function of a subset of inputs. With sufficient time for adjustment the firm may have an option of adopting or developing a new technology[15] which creates less socially undesirable residuals. The technology may range from a small change in the way some resources are coordinated to a major new investment in plant and equipment. In any case, at least under conditions of certainty, the basic marginal principle would be to compare the gains from the firm's resources when continuing with the same technology for another production period with the opportunity gains from owned resources which could be realized with the best alternative investment (including the new technology) during the same period.

If consideration of alternative technologies introduces nonconvexities into the set of feasible solutions faced by the decision maker, his criterion function will have to be evaluated for

[14] As our profession matures in the use of probabilistic economic theory economists like their theories may also become relatively more conservative.

[15] In agriculture such new technologies have largely resulted from research in the public sector or by oligopolistic firms in the factor markets.

each alternative or for subsets of alternatives to determine a global optimum. The theory of the firm can still be a useful analytical tool for determining local optima in such a process. When the problem of multiple optima raises its ugly head, the decision maker can never be certain of his choice unless he has the ability and resources to evaluate what may prove to be a large number of alternatives. Normally, available time and resources permit consideration of only a few alternatives so that the choice may be only nth best with n unknown.

From society's point of view the problem may be even more intractable. It is possible for society to get locked into the worst possible alternative and to develop a system of taxes which will support this position.

Externalities and nonconvexities in production

Thus far this analysis has assumed no technological externalities in the production process. Residuals from one producer were assumed to have no perceptible effect on the physical productive processes of another producer, except as the added residuals in the environment affect society's actions to place constraints on residual emissions into the environment.

Technological externalities may lead to nonconvexities in production. In such cases neoclassical theory of production does not provide a solution to the resource allocation problem. A hypothetical example from Starrett [8, p. 22] illustrates the idea. Assume that two firms can produce a given output y using the same environmental input x and that society has no more than 7/2 units of x, the environmental resource, to use on y. With subscripts used here to identify firms rather than inputs and outputs, the firm production functions are assumed to be as follows:

$$\text{firm 1:}\quad y_1 = 2x_1$$

$$\text{firm 2:}\quad y_2 = \frac{x_2}{y_1 + 1}$$

If y_1 and y_2 were identical goods, society's best interest would be served if the firms behave so as to

$$\begin{aligned} \max\quad & y_1 + y_2 \\ \text{s.t.}\quad & x_1 + x_2 \leq 7/2 \\ & y_1, y_2, x_1, x_2 \geq 0. \end{aligned}$$

The optimal solution from society's point of view is seen to be $y_1 = 7$, $y_2 = 0$. The first order conditions for a solution using the calculus define a minimum at the point (1, 3/2) in Figure 2. The corresponding values for x_1 and x_2 are 1/2 and 3, respectively.

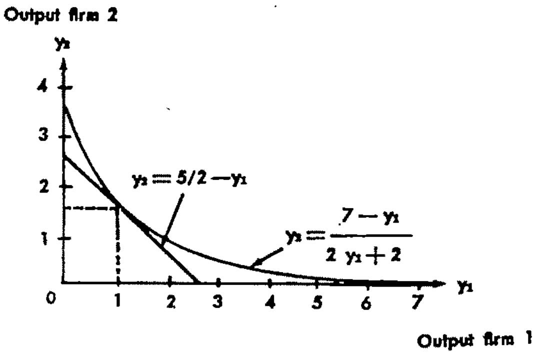

Figure 2

Starrett [8, p. 23] has shown that the minimum solution as well as the optimum solution does have a set of supporting taxes. However, in this case the optimum solution requires no taxes for support while the minimum solution requires that the output of firm 1 must be taxed at the marginal losses of firm 2.

Suppose the minimum solution had come about by historical development or accident, i.e., firm 1 had been using one-half unit of the environmental resource and firm 2 three units. Suppose further that an economist recognizing the externality suggested a solution by taxing. Firm 2 would not be taxed since its output created no externality. The tax against firm 1 would be set equivalent to the marginal damage on the output of firm 2, i.e., the marginal tax would be set equal to $\partial y_2/\partial y_1 = -x_2/(y_1+1)^2$ which when evaluated at the solution would give $-3/4$. The net price of the output of firm 1 (measured in terms of the output) would then be 1/4 unit. At this net price the optimal output for firm 1 would remain at a unit of y—the moral of the story being that the tax on the externality does not bring society closer to its optimal solution.

Other nonconvexities

Enterprises which become antagonistic provide an example of how environmental difficulties may create nonconvexities in the set of production possibilities faced by the firm. In fact, if two types of activity are perfectly antagonistic in an environment one precludes the other. Consider Figure 3 in which the firm has two alternative enterprises, cattle feeding

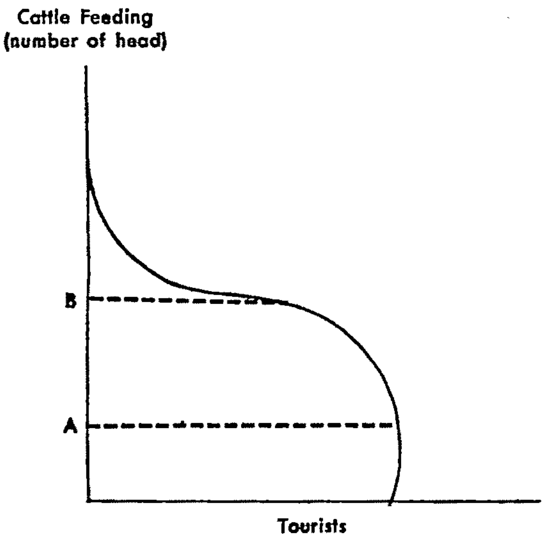

Figure 3

and providing services for people desiring a farm vacation.

A few cattle on feed may be complementary to visitors by providing an added attraction. At point A additional cattle feeding becomes competitive and at point B cattle feeding becomes antagonistic to the tourist enterprise because of environmental residuals.

In such situations neoclassical production theory may not explain firm behavior because of the existence of multiple optima. Under such circumstances firm profits at each optimum must be investigated to determine which one(s) is (are) global.

Decision making with nonconvexities

Zoning.—Zoning may facilitate resource allocation when nonconvexities arise. For years agriculturalists have recognized the importance of zoning as a method of allocating environmental resources. The basic theoretical notion behind land use maps and planning has been to "zone" or group activities so that complementary activities can be exploited and problems of antagonistic activities can be eliminated. That is, in a perfectly divisible world where production alternatives are continuous, activities would be grouped so that production possibilities would define a convex set, which hopefully included the optimum resource use.

Society also uses zoning as a device to avoid antagonistic activities in a given area.

New technology.—New technology offers a means of helping overcome nonconvexities in the set of feasible solutions so that choice combinations which previously did not exist come into being. Such solutions leave the decision maker with more freedom of choice. However, failure to anticipate the total effects of new technology has also aggravated residuals problems.

Jargon and Data

Myrick Freeman [4, p. 4], among others [1, p. 284], has complained about economic jargon when residuals enter the decision model. Indeed, common usage of many economic terms does not seem to recognize Nature's law of conservation of mass. For example, consider the most basic jargon of the theory of the firm. Carlson [3, p. 1] states, "To production we may attribute all the processes of combining and coordinating materials and forces in the creation of some valuable good or service." He goes on to define the valuable good or service as "the *output* · · · thought of as aggregates or sums of physical materials and forces" called productive services or inputs. Such usage, which is common, obscures the residuals problem by leaving the impression that stock resources and the services of flow resources are completely used up in the production process and that some valuable output is the only thing forthcoming.

The actual task of managing residuals must of necessity be accomplished at the micro level. To do this in a manner consistent with the desires of society, the producer needs to have knowledge of the input-output relationships of the complete production process. He also needs signals from society on how it values the goods and bads forthcoming from the process.

At the present time very little is known about the physical input-output relationships which include residuals. Even less is known about how to value alternative flows of goods, services, and residuals. It is rather vacuous to say additional data are needed. Theory and data are the raw materials, and applied economists will remain largely ineffective in efforts to predict or to test theories without data. The lack of definitive information adds to public anxiety about the environment. Both the lack of information and public anxiety make the task of structuring an institutional framework a rather arbitrary process.

Production economists in agriculture have traditionally been strong innovators in empirical analysis and have provided leadership in helping crop and animal scientists collect the

kinds of data needed for decision making. The challenge today is to carry some of this innovativeness into the area of welfare economics to help solve the problems of residuals management. This will mean that production economists will need to work more with engineers and other social scientists than they have in the past.

References

[1] Ayres, Robert U., and Allen V. Kneese, "Production, Consumption, and Externalities," *Am. Econ. Rev.* 59:282–297, June 1969.

[2] Carlson, G. A., "The Microeconomics of Crop Losses," *Economic Research on Pesticides for Policy Decision Making,* proceedings of a symposium, USDA, ERS, April 27–29, 1970, pp. 89–101.

[3] Carlson, Sune, *A Study on the Pure Theory of Production,* New York, Kelley & Millman, 1956.

[4] Freeman, Myrick, *The Economics of Pollution Control and Environmental Quality,* New York, General Learning Press, 1971.

[5] Georgescu-Roegen, Nicholas, "The Economics of Production," *Am. Econ. Rev.* 60:1–9, May 1970.

[6] Hoch, Irving, "Simultaneous Equation Bias in the Context of the Cobb-Douglas Production Function," *Econometrica* 26:566–578, Oct. 1958.

[7] McCall, John J., "Probabilistic Microeconomics," *Bell J. Econ. & Mgt. Sci.* 2:403–433, Autumn 1971.

[8] Starrett, David A., "Fundamental Nonconvexities in the Theory of Externalities," unpublished paper, Harvard University, March 1970.

[9] Zellner, A., J. Kmenta, and J. Drèze, "Specification and Estimation of Cobb-Douglas Production Function Models," *Econometrica* 34:784–795, Oct. 1966.

Discussion: Allen V. Kneese, *Resources for the Future, Inc.**

Max Langham has performed a useful service in addressing the theory of the firm and residuals management. As he notes, nothing very surprising emerges from his examination of the simpler models, but it is useful to have them set out explicitly. Also, he has been very successful in using quite a simple basic model to treat a number of diverse cases. This is an important achievement.

Most of my comments pertain to the later sections of the paper which treat uncertainty and technological change among other things. But I do have one or two comments on the earlier sections which set out the relatively simple static cases in which a firm is confronted with a constraint on residuals discharge or an externally imposed price for such discharge.

A general point is that in my view the whole analysis somewhat arbitrarily abstracts the individual firm from its industry. For example, in the first, and perhaps simplest, case where a tax is levied against the residual which is produced in fixed proportions with output, it is true that the firm's expansion path is unaffected. But whether the firm continues in the industry at all in the long run will no doubt be heavily influenced by whether a similar tax is levied on other firms in the industry. If it is not, in a simple model of price competition the firm is doomed unless for some reason a pure rental return was accruing to it. Maybe I am going beyond what Langham and, perhaps more broadly, what the profession understands as theory of the firm. But in my view the question of whether conditions in the industry are such that the firm can exist at all and what happens when there are significant differences in production functions among firms in a single industry must be part of a fuller theory of the firm. Nothing is learned about this by simply examining the conditions pertaining to the firm's expansion path.

Langham briefly recognizes this point, but I feel that treating it more systematically in connection with the various cases would improve the analysis. At least an explicit assumption should be made about whether all firms in the industry are affected equally by the restrictions or, if differentially, exactly how. For example, if a uniform effluent charge were levied on all firms in the industry, and if one recognizes that because of (say) age of plant components (revision in the technology of production is usually an evolutionary process) and specific features of the plant site the pertinent production functions differ somewhat among plants, the response would be quite different than if a uniform restriction is laid on all the firms. This is true even though, as Langham has demonstrated, when production functions are identical there is a restriction which will produce a result identical to the charge. In the more complex case, uniform restrictions will lead to

* I am grateful to V. Kerry Smith for his suggestions with respect to the comments on the Langham presentation.

higher costs for attaining a particular level of discharge for the industry as a whole than will a uniform charge. The limited empirical evidence we have suggests that the cost differences for the industry as a whole could be quite important.[1]

Langham moves from the case where residuals are a fixed proportion of output to one where they are a function of some subset of inputs. Again, this case is clearly and straightforwardly set out. The main difference in result is that a particular input associated with the residual will be used less if a tax or restriction is placed on it than it would otherwise be and that there is a rate of tax and a level of restriction which will produce equivalent results in terms of residuals discharge.

In this section, Langham might have made reference to and discussed the recent literature pertaining to "inferior and superior factors of production" [1, 6]. Among other things, this would have permitted him to add to the catalogue of perverse results he presents later. Whether inferior factors of production are any more than an intellectual curiosum, I don't profess to know.

The expenditure elasticity of a factor has been defined as follows: " · · · the proportional change in factor usage relative to the proportional change in expenditure on all resources while maintaining long-run efficient output" [6, p. 136].

It has been shown[2] that if, for instance, X_1 is an inferior factor which produces residuals and a tax is laid on X_1, thereby increasing its effective price, the use of X_1 will decrease while the equilibrium output of the firm will increase. More precisely, marginal cost to the firm will shift downward while average cost will shift upward and to the right. Thus, if industry adjustments permit the firm to survive equilibrium, output will increase. In the case of a superior factor, profits may increase when a tax is levied on the residuals generating factor.

Following his discussion of residuals generated by subsets of inputs, Langham uses his results to construct a chart showing the trade-off function between levels of product ("goods") and levels of residuals ("bads") which he says can be treated much like a production function. He then constructs community indifference curves which can be used to derive a social optimum. All this seems straightforward enough although, of course, all the usual difficulties with deriving community indifference curves apply.

But then he introduces indifference curves between goods and bads for the individual producer. These, he says, depend on his personal value system. This is a strange device to me, and I certainly would have appreciated some additional explanation. I suppose these curves are meant to reflect the producer's moral conscience in conflict with his cupidity. This departure from the normal assumptions of externality theory may be useful, but it flashes by too quickly to leave much of an impression. Langham passes the remark that the social optimum as seen by society and as seen by the producer is probably not far apart for a given state of the arts. What is the basis for this? Does it follow from the analysis?

In the next section, Langham begins to release his static deterministic assumptions and introduces the intriguing concept "risk of institutional failure." I have two general reservations about the development of this section. The risk of institutional failure (say, uncertainty about the level of effluent tax or other restriction to be encountered) is treated as an uncertainty in the production function similar to the vagaries of weather. I think it would be more realistically treated as an uncertainty in the price and cost parameters.

Thus, consider the following function the firm is taken to maximize. The variables and coefficients are self-explanatory.

$$\pi = PQ - P_L L - P_K K - P_R R + \lambda(Q - f\,\boxed{(L, K, R)}).$$

When considering the risk of institutional failure, the uncertainty term should be introduced, I think, in connection with the circled coefficient rather than the boxed-in function. It is not that the technological relations in production are uncertain, but rather that the tax (or other restriction to be placed on one of the outputs) is uncertain. Whether this greatly affects the result, I do not know, but certainly in most cases the marginal conditions for an optimum would be affected.

The other point has to do with treating uncertainty by means of a single statistic, expected value. To make this a valid figure on which to base a decision by the firm, one has to

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[1] See the discussion of the Delaware case in [5].

[2] See the paper by [1].

assume, among other things, unlimited financial capacity. The firm will no doubt be interested in other moments of the probability distribution, and where things are more uncertain than that, in how to protect itself against extreme events. One response was analyzed by George Stigler [7] many years ago in his classic article, "Production and Distribution in the Short Run." The firm may examine the range of possible outcomes and build flexibility into its response capabilities, even though this does not maximize expected value. Or the firm may build a closed-cycle (residual-free) process, even though the currently extant institutional restraints would not require it, because of the extremely, perhaps catastrophically, high costs of installing it once the plant is built. This latter response is more like applying the minimax criterion of game theory.

Langham then turns to the subject of the nonconvexities which may occur when externalities are present [3, 4]. I must say that I doubt that Starrett's example of a system of taxes which supports a nonoptimal situation has much practical significance. Firm 2, in the example, has the less efficient production process, even if Firm 1 is not producing, and it is necessary to invoke historical accident to bring about the possibility of nonoptimal taxes. Much more important, I think, is the government's frequent tendency to try to control residuals by specifying the particular technologies which must be used rather than by levying taxes on residuals. This really has the potential for freezing us into inefficient technologies.

Langham's comments on using zoning to control nonconvexities are well taken as, it seems to me, is his optimism about new technology. Research becoming available suggests that innovations induced by relative factor availabilities can produce highly productive technologies under very diverse conditions of factor proportions. A highly interesting study was recently published in this connection by Hayami and Ruttan [2]. They found that in spite of huge differences in land area per worker and in the relative prices of land and labor, both the United States and Japan experienced rapid growth in agricultural output over the 80-year period they analyzed. Moreover, the rate of increase in man-hour productivity was very similar in the two countries. This came about through a series of induced innovations of quite diverse types reflecting the specific factor endowments. This suggests that technology (more specifically, induced technological change) may be the savior rather than the villain of the piece, if we can get our institutional controls on residuals straightened out and make them effective.

I have little to say about Keith Bryant's paper because I feel even less qualified to comment on it than on Max Langham's. Also, I assume, I hope correctly, that Mancur Olson will treat Bryant in some detail. But I do have two general comments.

First, I am pleased to see a number of economists probing into how political collective choice processes function and, as in Bryant's case, how executive agencies work. For far too long, economists took their reasoning about resource use in the public sector up to some convenient point and then said, "well that's a political problem." This is highly unfortunate, because as Bryant shows here and O. Davis, J. Buchanan, W. Niskanen, E. Haefele, and other writers have shown elsewhere, economic tools can be used to illuminate collective choice and executive agency processes to a great extent.

Second, my only criticism is that I have the suspicion Bryant was not always as fastidious as desirable in examining alternative hypotheses which might also explain his results. The particular case I have in mind is where he presents and proceeds to confirm the hypothesis that with higher per capita income, price elasticity of demand for stamps will be lower and accordingly, in the interest of revenue, prices charged will be higher. I wonder if a simple hypothesis about equity (income redistribution) objectives would not have been as defensible.

After registering this small note of criticism, I must repeat, in conclusion, that I greatly applaud the effort.

References

[1] Ferguson, C. E., and Rodger Blair, "Inferior Factors, Externalities, and Pareto Optimality," *Quart. Rev. Econ. & Bus.* 11:17–25, Autumn 1971.

[2] Hayami, Yujiro, and V. W. Ruttan, "Factor Prices and Technical Change in Agricultural Development: The United States and Japan, 1880–1960," *J. Polit. Econ.* 78:1115–1141, Sept.–Oct. 1970.

[3] Johnson, Harry G., "Factor Market Distortions and

the Shape of the Transformation Curve," *Econometrica* 34:686–698, July 1966.

[4] JONES, RONALD W., "Distortions in Factor Markets and the General Equilibrium Model of Production," *J. Polit. Econ.* 79:437–459, May–June 1971.

[5] KNEESE, ALLEN V., AND BLAIR T. BOWER, *Managing Water Quality: Economics, Technology, Institutions*, Baltimore, The Johns Hopkins Press, 1968.

[6] MAURICE, S. CHARLES, AND C. E. FERGUSON, "The General Theory of Factor Usage with Variable Factor Supply," *Southern Econ. J.* 38:133–140, Oct. 1971.

[7] STIGLER, GEORGE, "Production and Distribution in the Short Run," *J. Polit. Econ.* 47:305–327, June 1939.

ECONOMIC GROWTH AND RURAL POVERTY

Chairman: T. T. WILLIAMS, *Southern University*

Technical Change and the Distribution of Income in Rural Areas*

CARL H. GOTSCH

It took both time and experience before the work people learned to distinguish between machinery and its employment by capital and to direct their attacks not against the material instruments of production but against the mode in which they are used.[1]

Karl Marx—1867

It is not . . . the new technology which is the primary cause of the accentuated imbalances in the countryside. It is not the fault of the new technology that the credit service does not serve those for whom it was originally intended; that the extension services are not living up to expectations; that the panchayats are political rather than development bodies; that security of tenure is a luxury of the few; that rents are exorbitant; that for the greater part tenurial legislation is deliberately miscarried; or that wage scales are hardly sufficient to keep soul and body together. [25]

Wolf Ladejinsky—1969

IT IS hardly a new idea to suggest that the adverse distributive effects of technical change in rural areas must be attributed primarily to the social and institutional context in which it occurs. Indeed, many prominent members of the agricultural economics profession have, over the years, pointed out that the characteristics of the social structure within which growth takes place are critical in determining its ultimate effect on the welfare of people and have insisted that institutions must be treated as variables in any relevant description of the development process.[2] It is only recently, however, that an increasing number of researchers have begun to heed these pleas for a more intensive investigation of the ways in which technology and institutions interact through time. This turn of events is perhaps less a matter of intellectual persuasion than it is the result of the rapidly accumulating evidence that the character of technical change in the rural areas has important implications for the orderly structural transformation of the entire economy. First, there is the problem of growth *per se*. A major portion of the agricultural land in a number of Third World countries is divided among small farmers; in such cases sustained increases in output in all sectors of the economy can be achieved only if a broad spectrum of the rural population takes part in the modernization effort. Second, and probably of greater importance in altering people's perception of the distribution question, is the apprehension in these same countries that technical change may produce a good deal of social and political unrest in the countryside. Recent studies have cautioned against the unbounded optimism that accompanied the first projections of the ultimate output effect of the green revolution, stressing that the conditions which limit its output potential are also the basis for severe distributional effects.[3] Lastly, the outbreak of urban violence in developed countries has underlined the potential long-run effects of technical change. In the aftermath of the riots in Watts and elsewhere, a number of urbanization studies have underscored what should have been obvious, namely, that an explanation of much of what has happened in U.S. cities is to be found in several decades of massive structural change in U.S. agriculture.[4]

* I am especially indebted to Walter Falcon and Peter Warr for discussions of an earlier draft of this paper. Helpful comments were also received from Arthur Mosher and William Thiesenhusen. Errors that remain are mine.

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[1] Karl Marx [28, p. 468]. Chapters XIII, XIV, and XV of *Capital* contain a variety of insights on the relationship between technology and social organization and deserve to be read in their entirety.

CARL H. GOTSCH *is a member of the Development Advisory Service and lecturer in economics at Harvard University.*

[2] See, for example, Dorner [9], Schaffer [38], and Schultz [39].

[3] For some recent writings that underscore this theme, see Brown [6], Hardin [18], Johnston and Cownie [21], Falcon [11], and Kaneda [23].

[4] See particularly, Kain and Persky [22].

There are undoubtedly a number of lessons about the distributive effects of technology which can be learned from the existing historical experience. However, most comparative studies—and the accompanying warnings and admonitions—continue to have an air of unreality about them; they dwell on the outcome of events (symptoms) rather than on the causes. For example, in the case of the United States, rarely does the analysis confront what ought to be key policy questions: If there were undesirable distributive effects associated with the introduction of a more efficient technology, why did it prove to be virtually impossible to alleviate them? What explains the failure to develop institutional and political instruments for mitigating the negative effects on, say, the welfare of sharecroppers and the small farmers? Why were policies with adverse distributive effects continued long after their cumulative impact was well understood? To stop short of these questions and others like them has tended to produce policy advice to developing countries that is at best politically naive and, at worst, the basis for development strategies that may be socially disastrous in the long run.

A thorough treatment of the political economy of technical change in agriculture would involve a lengthy consideration of the interdependencies between private agricultural interests, the manufacturing and processing sector, various research organizations, and general public policy.[5] In this paper I have tried to focus on a single aspect of the problem, namely, the relationship between technology, institutions, and people at the micro or community level. This necessitates treating the state (and particularly the development of technology) as exogenous to the system, a formulation that does not exclude the effects of government policy from the analysis, but fails to incorporate the feedback from the aggregate of local communities onto the activities of public institutions. Similarly, the aggregate price effects of technical change are not considered. Nevertheless, the rural community model and its specific application to Bangladesh and Pakistan underscore my main point: namely, that prognoses about the distributive effects of agricultural technology are of little help unless the characteristics of the technology are explicitly related to the social and political institutions of the countryside.

Investigating the Distributive Effects of Technical Change

A conceptual framework[6]

Predicting the dynamics of technical change at the community level requires an examination of four basic considerations and several important "feedback loops" between them. The first of these considerations involves the nature of the technology in the abstract; the latter three are best thought of under the broad heading of the social relationships of production.

The characteristics of the technology.[7]—Abstract technology, i.e., technology divorced from its institutional context has two characteristics of basic concern. First, there is the question of efficiency. A decade and a half of experience with community development programs has shown that a critical ingredient to any broad-based rural development effort is a significant improvement in the value-added by agriculture. While the precise order of magnitude needed to induce change is still a matter of debate, examination of a series of situations in which successful projects have been launched suggests that the increase to resources owned needed to overcome the reticence of traditional farmers to innovate must be on the order of 30 to 50 percent. Anything less than that is not

[5] For an important contribution to the development of such a framework, see Hayami and Ruttan [19]. Their notion of "induced innovations" (akin to the "feedback" concept used in this paper) serves two important functions: (1) it sets the issue of technological change in an appropriately dynamic context, and (2) it provides a mechanism by which certain types of institutional change become endogenous to the model.

While there is a similarity in perspective between their macro framework and the micro approach presented here, our views on the development of technology diverge somewhat when assessing the role of conflict between various groups in determining the direction of technological change. One need "not accept the Marxian perspective regarding the monolithic sequences of evolution based on clear-cut conflicts" to argue that the struggle by various social classes over the economic surplus is an important element in determining the characteristics of the technology that actually gets produced and diffused. For a discussion pertinent to this latter view, see Marglin [27].

[6] The proposed framework is complementary to the system developed by Mosher [31]. In some ways, it can be viewed as an institutional elaboration of his general perspective, i.e., any effective agricultural development strategy inevitably requires significant regional disaggregation.

[7] Elements of neoclassical production theory relevant to the subject of technical change and income distribution may be found in Brown [7] and Solow [41]. An earlier treatment of the material is in Hicks [20]. Some of the relations which are developed in Brown, Solow, and Hicks for a single sector are elaborated for two or more in Findley and Grubert [12].

sufficiently remunerative to produce the change in perceptions needed to insure widespread adoption among all classes of farmers.

A second important aspect of the technology that requires examination is its effect on factor intensities. Neoclassical economic analysis makes the important distinction between "neutral" and "non-neutral" technical change. The former may, for present purposes, be defined as a change in which there is a shift in the production function but for which the capital-labor ratios remain constant. Non-neutral change, on the other hand, may be either capital-using (labor-saving)—if the ratio of capital to labor employed in production rises—or labor-using (capital-saving)—if the capital-labor ratio falls. The significant point is that if factor prices remain constant, technical change which is labor-using increases the relative income share of labor, and capital-using technical change increases the relative share of capital.

The empirical estimation of the effects of any specific type of technology on factor shares requires a detailed micro analysis of that particular innovation. Although there is a customary equation of mechanical technology with labor-saving change and biological-chemical technology with land (capital)-saving change, this is often a matter of expositional simplicity rather than a description of the real world. For example, herbicides and weedicides are among the most labor-saving innovations that have been introduced into agriculture, while the tubewell and other mechanical devices for providing supplementary water are intensely labor-using. Even tractors, which in temperate climates are almost invariably labor-saving, can become labor-using where the environment of the tropics makes double and triple cropping possible. In short, a detailed analysis of the production process—the farming system—at the level of the producer unit is required to put the analysis of an innovation's effects on sound technical grounds.

The absolute magnitude and relative distribution of productive assets (especially land). —Both facets of this point are important—absolute size because it determines the extent to which individuals and firms can take advantage of the technology, and the distribution of assets because it is a first approximation to the social stratification of the rural community.

Fortunately, the divisibility of many of the most important inputs of the green revolution is such that the absolute size of the holding is irrelevant. New seeds, fertilizer, and pesticides are all perfectly divisible and, in principle, can be used with equal advantage by small and larger cultivators. There are, however, important exceptions. In cases where the control of irrigation water is critical, the investment indivisibility is sometimes borne by the state in the form of massive public works. But when the source of supplementary water supplies is privately owned tubewells, low-lift pumps, or other mechanical devices, the associated economies of the firm may be substantial.

An analogous situation exists with respect to institutional services. Apart from the question of overt discrimination, applications for credit and information take approximately the same time for everyone. However, the effects tend to be proportional to the magnitude of the output, a result that closely ties the benefit-cost ratio of acquiring services to holding size.

Those with a command over land assets are fortunate. For two other groups, tenants and landless laborers, opportunities to exercise a claim to a portion of the benefits of technical change of any sort are at best tenuous. The tenant is in a relatively better position than the landless laborer to take advantage of the potential for increasing productivity. First, he is in possession of some material capital (bullocks, equipment, etc.) whose scarcity value may rise as the result of new cropping patterns and increased power requirements generally. Second, the new technology may put a premium on management and thus provide a means for rewarding the human capital embodied in these skills. (The caveat here, of course, is that the technology must not be such that these skills become superfluous, i.e., extremely labor-displacing. In that event, the landlord may decide that the benefits of direct cultivation outweigh the cost of organizing and controlling a reduced day-labor force.)

The landless laborer has as his only asset his own raw labor power and those minimal skills associated with various forms of manual labor. Even with the introduction of labor-using technology and rise in the share going to that factor, his personal position is unlikely to show significant improvement. The surplus labor that exists in most rural areas, coupled with its inability to organize, insures that the supply of labor is likely to be quite elastic at close-to-subsistence wage rates.

The distribution of productive assets, especially land, is a pillar of the class structure in

rural areas. Though each situation will differ depending on its historical development, it is nearly always possible to identify some variant of (1) the landed aristocracy, (2) the capitalist farmer, (3) the peasant (subsistence) class, and (4) the groups that are economically and politically dependent on landowners, i.e., tenants and landless laborers. Agricultural growth inevitably affects the welfare of each group differently, depending on the characteristics of the technology and the magnitude of the assets they possess. The effect, however, transcends the mere fact that one group is made better off relative to another in terms of material benefits—the income distribution question. It alters the distribution of *power* as well. Thus information on the relative distribution of assets is needed to understand how technical change is likely to affect the *political* relationships between various groups. Without this knowledge, informed speculation about the dynamic effects of growth is virtually impossible.

The types of institutions and organizations that exist at the local level and the distribution of their services.—In most developing countries, the question of institutional services can be divided conveniently between those embedded in the private sector and those that are carried out by some unit of social organization.

It has frequently been pointed out in the literature that the *commodity markets* of most traditional societies can adjust to rather significant increases in output without great difficulty. But the circumstances of technological change virtually guarantee that well-established, well-stocked, efficiently functioning *input markets* for innovations will take considerable time to establish. As Ruttan [37] argues, this may be due largely to the relatively large amount of technical information that must accompany the sale of the new item, information rarely possessed by the traditional shopkeeper. It may also be due to broad government price policies that do not provide sufficient incentives for the private trade to enter the market or to the failure to provide the primary logistical facilities that make it possible to convey the inputs to areas of use at a profit. Whatever the case, these hindrances to the widespread availability of inputs embodying the innovation tend to have a severe distributional effect. For when local shortages occur, the distribution of new inputs becomes a function of the resources and power that individual farmers possess. Sometimes the ability to obtain access is a function of corruption and coercion; often it is the availability of private means of transportation to circumvent the limitations of the local sources of supply. The result is usually the same—small farmers go without.

Another aspect of the distribution of institutional services involves the incentives operating within the *organizations* that are supposed to serve agriculture. Experience has shown that much of the discrimination between large and small cultivators arises out of the motivations and attitudes forced on local officers by the structure and goals of the bureaucracy. For example, in credit institutions it is important to ask what the real administrative incentives to lending are. Is the reward to the lending officer in terms of amounts of money loaned or in terms of the number of loans made? How serious is a default from the point of view of a career loan officer? Numerous field studies have demonstrated that the criteria of advancement within organizations may be such that self-interested behavior at the local level runs directly against the broadly stated organizational goals.

Lastly, no evaluation of the dynamic potentials of an institutional structure should overlook the extent to which farmers have had experience in organizing and carrying out group activities of one sort or another. Effective cooperation is something that is learned; it does not spring full-blown into existence. Where this experience in participation is lacking, or where it has been perverted by inept and biased leadership, it may be exceedingly difficult to create new institutions that represent the class interests of the poorer group.

Social customs and traditions.—There is an important distinction to be made, at least in the short run, between the power of wealth and property and the power of role or position.[8] The first three considerations developed in this paper have dealt with the distribution of the former; the latter requires a dimension of analysis in which the perspective of the anthropologist and political scientist is brought into play. Particularly in traditional societies and for time periods that may last several generations, tribe, caste, kinship, race, and family continue to play an important role in the way

[8] For an extensive discussion of the role that these two sources of power play in the social stratification of societies at different stages of technological development (hunting and gathering, horticultural, agrarian, and industrial), see Lenski [26].

in which institutions function locally. Gaining an understanding of the social and cultural framework within which community decisions are made is therefore important in judging the ability of various social classes to organize institutions that would serve their interests.

The cumulative effects of the "system".—The second step in developing a broader conceptual framework within which to view the distributive effects of technology at the rural community level is to relate the various analyses described earlier to each other via a general *feedback* mechanism. Figure 1 suggests, in a purely descriptive fashion, that the characteristics of technology in the agricultural sector (A), the distribution of institutional services (B), and the distribution of productive assets (C), produce an estimate of the marketable surplus available from the rural community and a measure of the personal distribution of income. Taken together with the non-wealth attributes of local customs and traditions (D), the result is a distribution of personal income *and* power.

Three feedback loops complete the structure. The first, (E), involves the familiar process of capital accumulation. Here it is well to keep in mind that the availability of savings for the acquisition of additional assets is a function of the absolute surplus of the larger farmers and not of their relative position. Therefore, one would expect to find that pressure for the acquisition of scarce resources, particularly land, would exist even where technology was perfectly divisible and labor-using.

The second loop relates changes in income and power back to the institutions that serve rural communities. This is the most crucial point in the system for it determines to a large degree the extent to which agricultural growth can become the basis for a broad-based rural development program. Technical changes that affect the distribution of incomes can be expected to create a conflict between (1) those who do not have access to the technology because of institutional constraints and (2) the current recipients of institutional services who wish to maintain or enhance their organizational control. In the event that those seeking services try to create new institutions, they will be opposed by those currently in power. The desire to improve one's access to the services of institutions is, by implication, a desire to participate more effectively in the political decision making of the community.

Preservation of the *status quo* could therefore be expected under two types of conditions. The first would arise when the characteristics of the technology were such that mass participation in its benefits did not require social reorganization, e.g., new seeds and fertilizer. The second would occur where there was a definite need for cooperative efforts, but where political and economic forces of the *status quo* were sufficiently powerful to prevent the alteration or emergence of any organization dedicated to the interests of the excluded. On the other hand, social change involving increased access to institutional services would imply that some sort of dialectical process was at work in which neither of the polar conditions was a viable resting place. (The extent of the movement that could be expected would obviously be a function of *both* the intensity of feeling—awareness—of the various groups and the weight that they occupied in the income/power distribution.)

Lastly, there is the feedback from the effects of technology and asset distribution on the social and cultural traditions of the society, (G). As Weber [42] remarked, "Property as such is not always recognized as a status qualification, but in the long run it is, and with extraordinary regularity." However, as the *dotted* line in Figure 1 is meant to suggest, there may be substantial lags in the process. The old ways die hard.

In my view, the need to see that distributive questions involve such a *dynamic system* deserves special emphasis.[9] Not only does it draw attention to the interdependencies that exist among various facets of life in a rural community, but it also forces one to consider explicitly the cumulative effects of the constantly recreated disequilibria characteristic of sustained technical change in agriculture.[10]

[9] I have benefited greatly from discussions about the behavior of such systems from Dennis Meadows and members of the Systems Dynamics Group at the Massachusetts Institute of Technology. A brief description of the Group's work that has relevance for the question of agricultural transformation can be found in Meadows [29]. For a theoretical treatment of dynamic systems, see Forrester [13].

[10] Gardner [14] has recently examined the extent to which rural poverty in the United States is a result of the distribution of assets and to what extent it is a function of disequilibrium payments to factors. Using 1965 data, he concludes that in the West approximately 40 percent of the relative poverty is due to the former, 60 percent to the latter. The findings are reversed in the South with 90 percent due to asset distribution and only 10 percent due to factor market disequilibria.

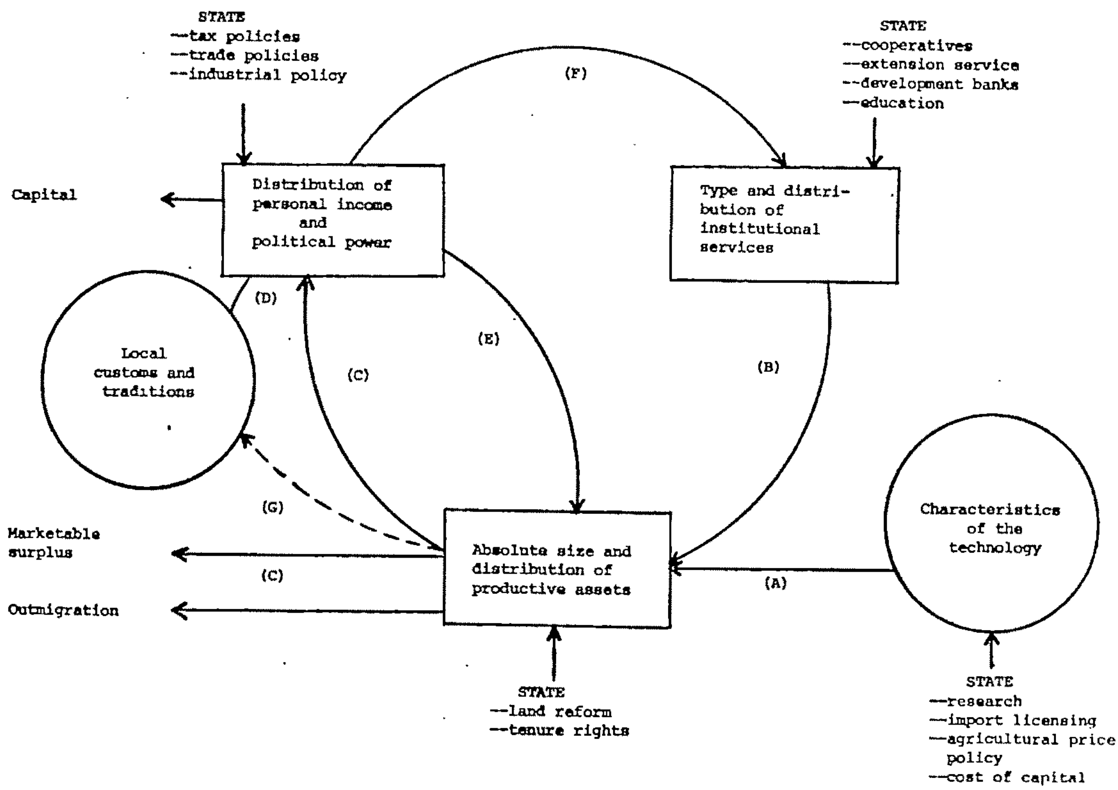

Figure 1. Flow Diagram of the Growth and Distribution of Farm Income at the Community Level

The possibilities for influencing the tendencies of the system through government policies are numerous and those shown in Figure 1 are only illustrative. While most of the individual elements have been widely discussed in the literature on agricultural development, what has been overlooked is that supposedly independent *policies* also have overall positive or negative cumulative effects. Indeed, in many cases, the presence of cumulative effects offers the only chance of making meaningful reforms that in and of themselves mean little. For example, the importance of limited land reform measures rests less on specific economic or social criteria than on the reform's role in "freeing-up" the system, i.e., in creating new policy options elsewhere in the system which are not immediately related to the initial change. Eliminating some of the larger landlords makes possible rural cooperatives and group equipment pools that would otherwise be difficult to organize. These organizational forms in turn have an effect on the distributive impact of the technology that is introduced—which in turn affects the distribution of land assets. Too often, these induced effects have gone unrecognized in the static analysis which characterizes most planning exercises. The result has frequently been a series of inherently contradictory programs, each aimed at a different point in the system and whose joint effect has been to frustrate the overall intent of government policy.

Alternative development patterns: Bangladesh and Pakistan

The need to see the distributive effects of technology in terms of the previously cited considerations can best be made concrete by examining related case studies. The following section provides a brief analysis of the introduction of the same innovation into two areas of South Asia having significantly different relationships between land, institutions, and people.

Technology—the tubewell.—In both regions the ability of farmers to control an artificial water supply is crucial to the effective use of the improved seed-fertilizer package. In Pakistan, the need for irrigation is obvious; it is an arid area with the largest part of the region averaging less than 15 inches of rainfall per annum.

Table 1. Size distribution of holdings in Comilla District, Bangladesh, by tenure status (1960)

Size (Acres)	Operated				Owned			
	(1) Number (000)	(2) Percent	(3) Area (000)	(4) Percent	(5) Number (000)	(6) Percent	(7) Area (000)	(8) Percent
under 0.5	137	23	35	3	154	26	33	3
0.5–1.0	119	20	87	8	83	14	44	4
1.0–2.5	198	33	324	30	154	26	273	25
2.5–5.0	99	17	343	31	118	20	371	34
5.0–7.5	25	4	149	14	35	6	196	18
7.5–12.5	12	2	109	10	47	8	120	11
12.5–25.0	2	*	40	4		*	55	5
25.0–40.0		*	4	*		*		*
40.0–over		*	1	*		*		*
	592	100	1092	100	591	100	1092	100

Sources: [33]. The size distribution of land owned based on my calculations. For details see Gotsch [15].

Bangladesh cultivators however are also interested in irrigation, for although the monsoon delivers vast amounts of rainfall in the summer months, the sunny winters are almost entirely devoid of precipitation. Except for a few low-lying areas, a *boro* or winter rice crop without supplementary water is impossible.

The water-producing technology that has resulted in the most dramatic impact on local farming systems in both areas is the tubewell. In its simplest form, it consists of a 6–8 inch tubular shaft sunk to a depth of 50–150 feet (depending on the characteristics of the soil and the level of the water table) to which a centrifugal pump is attached. The latter may be run by either an electric motor or a 15–20 hp. one-cylinder diesel engine.

Farm management studies show that there is relatively little difference in many of the engineering and economic aspects of the technology in the two areas. Methods of installation and costs are similar—something to be expected since Bangladesh essentially borrowed the technique from the West. Rates of return tend to be highest in the non-irrigated arid regions of the Punjab, but where canal water deliveries are on a perennial basis, they are approximately in line with the more profitable wells in Bangladesh. Studies also show that the potential amount of land irrigated with each well does not vary appreciably. In the rice-growing areas of the Central Punjab, on the order of 60–80 acres would be associated with each well; in Comilla District, farm management data suggest the figure would be closer to 50 acres.

Direct estimates of the effect of tubewells on factor shares are not yet available from farm management surveys. However, an examination of the before and after solutions of linear programming models developed for both areas shows that the hours worked annually in the optimal solution increases from 30 to 75 percent, depending upon assumptions about the permissible cropping patterns.[11] Since the tubewell represents only a very small increase to the total stock of capital represented by the land, bullocks, and equipment of the area it irrigates, capital-labor ratios have declined significantly. Thus, in both Bangladesh and Pakistan the tubewell must be characterized as a labor-using (capital-saving) type of technological change.

In short, the characteristics of the technology are similar for both areas. However, its impact on the ultimate structure of the rural community is likely to be quite different.

Land tenure relationships.—As Tables 1 and 2 indicate, tenure patterns are quite different in the two regions. The median holding size for Comilla District in Bangladesh is between 1.0 and 2.5 acres; for Sahiwal District in Pakistan, it is between 7.5 and 12.5 acres. Moreover, there is considerable difference in the distribution of land. As the Lorenz curves in Figure 2 indicate, land is distributed much more equally in Comilla District (less than 1 percent) and the owner-*cum*-tenant class com-

[11] For a programming analysis of the effect of technology on farm operations in Pakistan, see Gotsch [16, 17]. A similar analysis for Bangladesh farms using a stochastic programming approach can be found in Smith [40].

Table 2. Size distributions of holdings in Sahiwal District, Pakistan, by tenure status (1960)

Size (Acres)	Operated				Owned			
	(1) Number (000)	(2) Percent	(3) Area (000)	(4) Percent	(5) Number (000)	(6) Percent	(7) Area (000)	(8) Percent
under 5.0	95	43	184	9	48	43	98	5
5.0–7.5	19	13	164	8	21	19	200	10
7.5–12.5	43	19	399	20	19	17	295	15
12.5–25.0	42	19	693	35	17	15	305	16
25.0–50.0	12	5	364	19	6	5	782	40
50.0–over	2	1	149	8	1	1	273	14
	223	100	1953	100	112	100	1953	100

Sources: [33]. The size distribution of land owned based on my calculations. For details, see Gotsch [15].

prises less than 25 percent of the total farm population. In Sahiwal District, however, more than 50 percent of the units are operated by full tenants.

With respect to the tubewell, the significance of the data on farm size is fairly straightforward. Whereas in Sahiwal, nearly 50 percent of the cultivators own sufficient land to purchase and utilize a tubewell either individually or in partnership, less than 1 percent could do so in the Comilla. Even if only the collateral limit were binding, the number of farmers in Comilla with sufficient resources to finance such an investment is not above 15 percent. The result is a powerful incentive for some type of group activity that will enable individuals to install wells jointly.

Types and distribution of institutional services.—For all practical purposes, the institutions serving Pakistani cultivators in Sahiwal District have a strictly top-down style of operation. Even the Cooperative Department relies very little on grass-roots participation. These so-called "nation-building" departments are severely biased against small farmers. Whether it is the transmittal of knowledge through the extension services, access to credit, or the sanctioning of additional canal water supplies, the distribution of services is primarily to the larger cultivators.

To some extent, this system has been overcome by the farmers themselves. In areas where input supplies are readily available, virtually everyone, large or small, has adopted the new seeds and learned to apply fertilizer to them. There is some evidence that small farmers have lagged a year or so behind their larger neighbors and are still applying less-than-optimal dosages of fertilizer. But the difference is not striking.[12]

With respect to the critical question of supplementary water, however, it is a different story. In Pakistan, subsidized credit available for the purchase of tubewells has gone almost entirely to large farmers. This was due partly to collateral standards and the desire of officials in the lending agencies to insure that as little risk as possible be associated with the transaction, partly because of a greater conversance

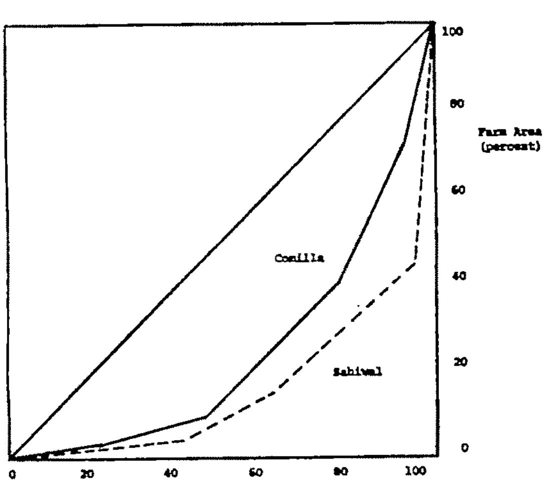

Figure 2. Distribution of Owned Land in Comilla and Sahiwal Districts

[12] The broad-based participation of small farmers in the first stages of the seed-fertilizer revolution has now been widely documented. For example, for Pakistan the relevant studies by Eckert, Hussain, the Punjab Planning and Development Department's Survey Unit, Rochin, and Loudermilk have been summarized in Rochin [36]. These results have been reinforced by survey material presented in Naseem [32].

For Comilla District in Bangladesh, similar evidence is found in Faidley and Esmay [10].

on the part of large farmers with bureaucratic procedures (both honest and dishonest) and partly because of their influence with other agencies whose duty it was to supply electric connections. The result has been an increase in private wells from 4,000 to 12,000 during the past five years, a rate that has substantially surpassed all expectations.

Unfortunately, despite the large increase in wells, small farmers have found that no really satisfactory *market* for supplementary water exists. It has become apparent, for example, that depending on the particular distribution system, tubewells have spatial characteristics which tend to give owners a quasi-monopoly position vis-a-vis those who would buy supplementary water. Also, individual tubewell owners may or may not be in a position to extend credit for water sold. Without a ready source of production credit, the result is that small farmers apply less water per acre and, among other things, lose the important physical complementarities that exist in the green revolution package.

Tubewells in Comilla were introduced under entirely different institutional circumstances. As indicated earlier, the absolute holding size is such that it was impossible for individuals to sink the bore holes and install the necessary pumping equipment themselves. The result was that in 1965 the Central Cooperative Association of the cooperative system organized initially by the former Pakistan Academy for Rural Development at Comilla began its program of helping primarily village cooperative societies install the wells.[13] In each case, wells and pumps were installed only where the village cooperatives had made the request for such equipment and had paid a portion of the rental fee in advance. The rental fee was a flat rate and independent of the acreage irrigated. Digging and maintenance of the irrigation channels and the setting up of a procedure for distributing water among the cooperative's members were the responsibility of the primary village society. They also determined the sale price in the event that water is sold to non-cooperative members.

As one would expect, with the emphasis on village organization, the spread of tubewells in Comilla has been less rapid than in Sahiwal. (The speed has also been affected by rapid growth in the use of low-lift pumps for lifting the water directly from streams and ponds.) However, the acreage under irrigated winter crops rose from approximately 1000 acres in 1964–65 to 6000 in 1969/70.

The impact of tubewells on the size distribution of income

Little direct evidence regarding the distribution of income, either before or after the green revolution, exists for the rural areas of Pakistan. However, knowledge of the incidence of use by farm size, coupled with the effects on synthetic farm management models of incorporating the advanced technology, permits a number of judgments to be made regarding the distributive effects that should be expected.

According to the Farm Mechanization Survey of 1968 [34], 70 percent of the tubewells in Pakistan were installed by farmers having more than 25 acres. Seven percent were installed by tenants or, what is more frequently the case, as an investment by businessmen from the city. Only 4 percent were installed by the size group that incorporates the majority of Pakistan's cultivators, namely 0–13 acres. (Though these figures are for the region as a whole, they reflect conditions in Sahiwal District quite closely.)

However, as indicated earlier, installation figures do not accurately reflect the extent to which small cultivators have benefited from improved water supplies. A market in irrigation water does exist, supplied for the most part by owners with less than 50 acres who have excess capacity. Indeed, Naseem's survey [32] of small farmers in Sahiwal District shows that the purchase of water by small farmers is widespread. Unfortunately, the amounts purchased fall well below what would be considered optimal if a competitive market in water prevailed.[14]

The effect of the additional water at competitive prices on the net revenue of the cultivator is substantial. Farm management models suggest that even without improved seeds and fertilizer, net revenue increases by about 35

[13] The literature on the Comilla program has become extensive. For a summary statement, see Raper *et al.* [35].

[14] For example, in Sahiwal District, Pakistan, small farmers purchased approximately 10 hours of supplementary tubewell water annually per acre [32]. Mohammad's earlier study [30] of the same area shows larger farmers with wells applying nearly 20 hours of water per acre. Both results are consistent with estimates based on the parametric variation of water prices in linear programming models of the area. See Gotsch [16, 17].

Table 3. Number of cultivators growing winter crops by farm size, Comilla Thana, Bangladesh

(1) Farm size, acres	(2) percent coop-members with given farm size	(3) of members growing winter crop, percent with given farm size				(4) percent non-members with given farm size	(5) of non-members growing winter crop, percent with given farm size			
		1966	1967	1969	1970		1966	1967	1969	1970
nil	2	—	—	3	2	24	—	2	7	4
0–1	12	22	11	11	18	41	16	23	22	27
1–2	43	36	33	41	32	13	41	42	32	22
2–3	18	19	29	11	11	12	30	20	15	26
3–5	16	19	18	24	19	7	13	10	24	15
over 5	8	3	8	8	18	3	3	2	2	5

Source: Faidley and Esmay [10].

percent.[15] This is a function not only of an increase in cropping intensity, but also of a shift to higher valued (and more labor intensive) crops such as cotton and sugar cane. When the possibility of utilizing advanced biological and chemical innovations is also introduced, supplementary water produces a 45 percent increase in net revenue. The conclusion is therefore inescapable that so long as small farmers are finding it difficult to gain access to its services, the private tubewell will be a source of increasing income inequity in Pakistan.

In Comilla District, research on the adoption of highly divisible technology such as new varieties and fertilizer shows a pattern similar to that of Sahiwal District. Nearly all farmers, regardless of size of holding or participation in the cooperative scheme, have benefited absolutely from the green revolution technology. Usually there has been a lag of one to two years between the early adopters (large farmers or cooperative members) and late adopters; however, the diffusion—if not the same levels of input use—of simple divisible technology has spread quickly to virtually all members of the farming community.

However, like Sahiwal, the Comilla experience also demonstrates that differences occur between individual farmers when access to a supplementary supply of flexible irrigation water is involved. In this case, among cooperative members farm *size* has had a relatively small effect on the extent of winter (dry season) cropping. As Table 3 shows, the proportion of co-op members growing winter crops who farm on less than 2 acres is approximately the same as that size group's representation in the overall sample (52 percent of those growing winter crops; 57 percent membership). Therefore, the probability is that any given farmer in the co-op winter crops is independent of his size. The same cannot be said of non-members; the proportion of winter croppers farming on less than 2 acres is about the same but the proportion of non-member farms in that category is much higher. Even more telling with respect to the water variable is the intensity of winter cropping. Table 4 suggests two observations: (1) that when supplementary water supplies are available, small farmers will achieve higher cropping intensities than large farmers, and (2) that cooperative members have a much larger portion of their farm land under irrigation than do non-members.

The extent to which farmers have benefited from increased water supplies has been investigated by Smith [40]. Using a stochastic programming approach to capture the vagaries of the monsoon-dominated weather, he concludes, for example, that a farmer of the 1.5–2.5 acre class has been able to more than double his income under modern technology. The nature of the Smith analysis makes it difficult to determine what part of the increase is related to proved water supplies and what is related to other factors. However, given the fact that the winter crop is entirely dependent on supplementary water, the contribution of tubewells alone is probably even higher than in Pakistan. One can only conclude from this that the widespread participation of the small and middle peasant group in the Comilla program will

[15] The interaction of a flexible supply of supplementary water and improved seeds and fertilizer is significant. If the two changes from traditional to advanced technology (tubewells and HYV) are taken independently, they yield an increase in net revenue of 35 and 25 percent, respectively. The sum of their individual increases (60 percent), however, is well below the increase produced when both are introduced simultaneously (85). This has nothing to do with the kind of physical complementarity of which agronomists speak, but results rather from the opportunity to increase the acreage under the profitable HYV when a flexible supply of supplementary irrigation water is available.

Table 4. Percent of land owned by the farmer which is winter cropped, Comilla Thana, Bangladesh

farm size, acres	Coop-members 1966	percent farm in crop 1967	1969	1970	Non-members 1966	percent farm in crop 1967	1969	1970
0–1	80	60	195[a]	208[a]	—	—	58	77
1–2	53	50	77	79	—	—	53	55
2–3	46	56	75	66	—	—	23	59
3–4	25	65	66	70	—	—	38	23
4–5	—	22	51	47	—	9	25	66
over 5	—	48	60	56	—	—	—	25
average	44	53	68	67	—	9	42	53

[a] Numbers larger than 100 are the result of individuals renting land in addition to the land they owned.
Source: Faidley and Esmay [10].

tend to maintain the relatively equalitarian distribution of income that currently exists.

The overall conclusion that the first-round distributive effects of tubewells in Comilla are equalitarian is not, however, without caveats. As Faidley and Esmay [10] indicate, very small farmers and landless laborers generally have not participated in the cooperative movement. Therefore, the benefits from broadening the base of technological diffusion have not taken the same form as they did among those who owned land. However, given the fact that the new seed-fertilizer-water package is labor-using and requires 50–70 percent more labor per acre and that the overall demand for labor in the area is a function of the number of acres brought under the new technology, the large increases in acreage brought under winter cropping by cooperative members in the small size classes should have some positive impact on the welfare of landless and near landless laborers.

Traditional social organization and the dynamic effects of tubewells.—The argument thus far has been a simple illustration of Marx's comment that the distributive effect of machines lies not in the technology but in the institutional framework within which they are used. Understanding the ultimate effect of the tubewells, however, also requires an assessment of the second-round effects, i.e., the impact of the technology *on* the existing institutional and social structure. As indicated previously, it is an important and largely neglected set of policy questions that asks: "Which institutions are strengthened, which are undermined? Which social classes are likely to become more powerful, which will be weakened? Are these changes consistent with the country's overall development strategy?" It is obvious that innovations need not induce desirable institutional change; indeed, they may reinforce the very conditions that stand in the way of broad-based participation in the development process. In the extreme case, large short-run gains accruing to certain groups may seriously distort the community's long-run growth prospects.

To a considerable extent, the answers to these questions are already implied in the material presented earlier. Wealth is power, and one would expect that the beneficiaries of increased incomes would be strengthened in their conflicts with other classes. Similarly, the institutions that control or provide the profitable inputs will increase in stature and power. However, in the short run, power—and thereby the ability to influence the course of events—is also vested in traditional roles and positions. Thus, before going on to a prognosis about the ultimate distributive effects of tubewells, a short digression is necessary on the style of village level politics.

Rural politics in Pakistan has a distinctively *factional* flavor.[16] That is, individuals in the village do not form groups or allegiances because they have a common goal that their cooperation would service. Rather, they are "recruited" by one or another of the local political leaders who offers some sort of transactional relationship. "Recruitment" takes two forms: among those who have a choice in the matter and among those who do not. The latter are epitomized by the sharecroppers and landless laborers whose dependence upon the favor of the landlord for their livelihood predetermines their allegiance.

[16] See Alavi [1]. I am grateful to Professor Alavi for a number of stimulating discussions regarding the implications of village level politics for development programs and policies.

For others, namely the small and medium land owners, there are certain choices to be made. It is around this group that intense political competition between rival faction leaders takes place. No holds are barred in this struggle: cattle are stolen, women are abducted, and buildings are demolished. Use of "goondas" or hoodlums as enforcers is widespread. Frequently when two equally powerful individuals are competing for the allegiance of a particular kinship lineage (*biraderi*), composed largely of small holders, a virtual state of siege may ensue. In some cases, the pressures are such that the kinship group, which is the basic unit of social interaction in Punjabi Muslim villages, may have to divide against itself politically in order to acquire the "protection" of competing leaders.

Obviously, the *vertical* alignment of factions is in direct conflict with the *horizontal* alignment of classes. Where economic dependence is the rule, as in the case of sharecroppers and landless laborers, class alignment is virtually impossible.[17] But from Alavi's [1] description, class alignments needed to produce institutions capable of representing the interests of small farmers would be extremely difficult for small landowners to organize as well. The necessary conditions would appear to be a *biraderi* or kinship lineage composed largely of such small farmers and the physical proximity of the group in a single village or other contiguous area. (The latter element is necessary in order that they may be able to protect themselves.) Unfortunately, such distributions of holding size and kinship characteristics are not the normal pattern in the Punjab. The result is a domination of village political life by the various faction leaders.

Given the importance of factionalism, the effect of tubewells and other modern technology in Pakistan has been to undermine further any possibility of organizing agricultural institutions that could aid small farmers. First, the technology at the disposal of faction leaders has increased considerably their ability to maintain the vertical relationship described earlier. The credibility of eviction or dismissal threats is considerably enhanced by the recent innovations and is likely to be a powerful factor in disciplining the labor force.

Secondly, while factional feuding continues, there is evidence that efforts are being made by the larger farmers to develop a united front at the highest policy levels (e.g., organizing the Punjab Farmers Association). To the extent that this effort to organize horizontally at the top is successful, the movement has important implications for low-income agriculture. Thus far, the energies of the "new" class have been devoted largely to insuring that their prosperities will continue.[18] Lobbying efforts against land reform and on behalf of a favorable tax policy and the maintenance of price supports have been quite effective. But I would anticipate that if necessary the group would quickly become an instrument of opposition to the establishment of any rural institution which might be effective in dealing with poverty problems. Though they may remain rivals at the village level, large farmers have a common interest in maintaining a factional style of politics, a style to which class-based organizations among the smaller farmers would pose a severe threat.

To some extent, political life in Comilla District of Bangladesh also exhibits a good deal of factionalism. But, for a variety of reasons its impact tends to be relatively muted. First, very little full tenancy exists. As a result, control over the access to the means of production via that channel is limited. Second, the absolute size of the holdings is such that significant surpluses do not exist except among what might be called the very large farmers. Indeed, the past several decades of increasing population pressure has reduced many individual members of what were historically *sadari* (dominant) kinship lineages in the village to the subsistence or middle peasant role.

Bertocci [4, 5] has pointed out that it is this middle peasant group which assumed the crucial leadership role in organizing the village cooperative structure. On the one hand, lineage

[17] This description of the political aspects of economic dependence might as easily have been written about Mississippi. For example, Holmes County has a highly sophisticated network of black organizations and blacks play an important role in the county's political life. In neighboring Sunflower County, with a higher percentage of black voters, there is relatively little black communal and political activity. Observers have traced much of this difference between the two areas to the large number of small, economically independent black farmers in Holmes. Their presence is a result of several pilot programs initiated by the Farm Security Administration during the late 1930's in which black sharecroppers were helped to purchase the land they tilled. For a brief description of these projects, see Bagdikian [2].

[18] For an extensive discussion of the political implications of the concentration of benefits from the green revolution, see Burki [8].

membership conveyed a status that legitimized their leadership position in whatever form of social change the village undertook. On the other, their immediate econmoic interests were consistent and best served by the original organizing efforts aimed at making small farmers more independent of the money-lending classes.

The tubewell in turn has been a powerful instrument in solidifying the community organizing activities that began prior to 1965 and providing the middle and small peasant group with sufficient resources to break the economic hold of the very large farmer-trader-moneylender group. Indeed, until the military disruption of recent months, there was some evidence that the moneylenders were being successfully withstood as they made a number of attempts to subvert the village level cooperatives.[19]

In addition to increasing the relative power of the middle peasant class, the green revolution in Comilla has supported—often indirectly—a variety of other development programs with positive distributive effects: primary education, health, adult literacy, and training for women to mention but a few. Indeed, the list reads somewhat like the community development programs of a previous decade. The significant difference in the Comilla case, of course, is that these programs are now built on a solid base of increasing productivity in agriculture.[20]

[19] A favorite trick of the large farmer-*cum*-moneylender has been to join the co-op, take out the maximum possible loan, and then refuse to repay, hoping that this would drive the organization into insolvency. See Khan [24].

[20] There is reason to believe that the Comilla program could be replicated in most parts of Bangladesh; what is not clear is that it would have been permitted to do so. For the increase in the economic well-being of the small and medium farmer must ultimately pose a direct threat to the national political position of the surplus farmer-contractor, a class that continued to exercise significant influence in the post-Ayub governments. As Barraclough [3] has observed:

> The paths of development history are strewn with the debris of well-intentioned and often well-planned and executed projects that have failed to have a wider impact because they were not in harmony with the course of events in the national society. These experiences are almost always useful, for research and training—for learning more about the real problems and possibilities. But they may not have much direct impact on the character of rural development outside their own limited areas. Nor are they usually reliable indicators of the types of institutional change that would be feasible on a national basis.

In other words, even if the rural system that exists at the level of an agricultural community is such that the adverse consequences of technical change can be minimized, its ultimate distributive effects cannot be detached from the economic and social structure of the society as a whole.

Concluding Comments: Some Generalizations

The theme of this paper has been that a meaningful investigation of the distributive effects of technology must be carried out in the context of a conceptual framework that shows how the characteristics of technology, local institutions, and the rural social structures are related to each other at a point in time and how these relationships can be expected to evolve in a dynamic rural system.

I hypothesize, on the basis of alternative combinations of the considerations described earlier, that comparative studies will reveal a number of distinct types of development situations. The four that follow are by no means exclusive but they involve some of the more sensitive parameters in the system.

Type I. New technology: simple, divisible, labor-using
Holding size: small, relatively equalitarian
Institutions: top-down, no community participation
Social organization: individualistic, loosely structured

This type of situation appears to be fairly common in Africa. The highland areas of Kenya into which new maize varieties were introduced offer a specific example. It is also characteristic of a few regions in Latin America; e.g., it seems to fit rather well the description of the Puebla Project sponsored by the Rockefeller Foundation in Mexico.

Output can increase fairly rapidly under such conditions provided the technology is really profitable; extension efforts required are usually fairly minimal since the technology is simple.

The first-round distributive effects of technology in such cases are likely to be minor. However, there is also likely to be little pressure for further community development. Credit would pose severe problems for only the lower third of the population and unless there was a severe marketing problem, as in the case of some sort of cash crop, efforts at organizing cooperatives and other types of communal activities are likely to be slow.

The same holds true for social and political organization. The problem, of course, is not one

of the repressive measures of dominant elites; it is simply that the changes in the underlying mode of production do not result in contradictions with the way in which the society is already organized. Without the presence of significant inconsistencies between the nature of the technology and the institutional structure, the demands for any type of rapid social change are likely to be small.

Type II. New technology: complicated, lumpy, labor-using
Holding size: small, relatively equalitarian
Institutions: top-down, no community organizations
Social organizations: individualistic, loosely structured

This situation would be typical of Bangladesh and areas in South and Southeast Asia requiring a mechanical technology for small-scale irrigation but in which labor-displacing mechanization of rice culture is not far advanced. Such a configuration presents both difficulties and opportunities for broad-based rural development. The difficulty resides in the fact that if no institutional structure exists in the countryside, an outside catalyst is generally needed to introduce and organize people in such a way that the technology can be jointly used. In some cases, this has been done by outside entrepreneurs creating a market for services (pump rental agencies in Malaysia), but more generally the efforts of a central authority or a political party are necessary. Where these organizational activities are not forthcoming, development is likely to stagnate. However, this situation more than any other has the potential for evolving into a program in which development is something broader than increasing agricultural output. If the "lumpy" technology is truly profitable, it can become the catalyst around which organizations for introducing or creating a variety of additional services for the majority of the farming community can be built.

Type III. New technology: simple, divisible, labor-using
Land distribution: relatively unequal
Institutions: top-down, no community organizations
Social organization: hierarchical

As the research reported here suggests, in those areas of Asia and the Middle East where the seed-fertilizer revolution has found sufficient water control (artificial or natural), it has spread quickly to farmers of all size groups. Thus, output can be expected to increase fairly rapidly if the technology is clearly superior to traditional practices. Although there has been some additional delay in the diffusion to the smaller farmers, and they have lagged somewhat in applying the full measure of purchased inputs, the adverse distributive effects in such a situation have not been pronounced. The likely pattern would involve small farmers becoming better off relative to their previous position but worse off relative to their larger neighbors. One would expect relatively little tenant eviction, since under this technology the problem of controlling and managing the labor force would remain. However, since it is absolute surplus that determines ability to accumulate additional land, considerable economic power would be wielded by the larger farmers. Insofar as these highly divisible innovations did not involve the type of herbicides that seriously reduce the demand for labor, it is possible, indeed likely, that the overall demand for labor would increase.

Type IV. New technology: complicated, lumpy, labor-displacing
Land distribution: relatively unequal
Institutions: top-down, no community organizations
Social organization: hierarchical

Obviously, it is this general situation that tends to produce the most serious questions about the distributive effects of technology. An excellent historical example would be the Mississippi Delta; currently, similar conditions exist in most of the Latin American countries. If policies that encourage mechanization are continued, it is also the most likely prognosis for Pakistan. As a development situation, it presents a number of difficulties. First, there is the problem of insuring access of the majority of the farmers to the technology. The evidence in both developed and less-developed countries suggests that markets to convert lumpy stocks of mechanical innovations into flows of services may be a less than fully effective diffusion instrument as far as small farmers are concerned. Thus, the disparity between those classes having the resources necessary to utilize the technology effectively and those who do not may develop rather rapidly.

Second, the class distinctions existing in such

a situation make it extremely difficult to organize badly needed cooperative institutions. Although the technology produces conflicts in the existing structure that would dictate some sort of group activity, its political threat if organized is such that those who are not in need of the joint service are likely to use their power to render it ineffective. In cases where the lumpy technology is also labor-saving, the existing social stratification may be greatly enhanced.

Third, it is under such conditions that technical change may become associated with overt social conflict to produce a rate of innovation and diffusion quite inconsistent with prevailing factor endowments. Strikes and social movements such as the recent threat of Punjabi sharecroppers to withhold their rents and the Freedom Summer in Mississippi may raise the wages of labor as *perceived* by the farm operator to a point well above their social cost. Where this is also accompanied by an undervaluation of capital, labor-displacing technology may be introduced with extraordinary rapidity.

The foregoing generalizations are obviously in the nature of hypotheses that require extensive empirical investigation. However, it is my impression that insofar as designing rural development programs and projects is concerned the general principles of "integrated rural development" would benefit from further disaggregation along the lines suggested by the foregoing typology. Too few studies confront explicitly the feasibility of their proposals in the context of a particular system. Where institutional experimentation is highly constrained—as is frequently the case—research that would relate quantitative changes in system parameters to qualitative changes in the system's behavior is badly needed. The latter is frequently a prerequisite to the implementation of programs and policies that benefit a majority of the residents of the rural community.

References

[1] Alavi, Hamza A., "The Politics of Dependence: A Village in West Pakistan," *S. Asian Rev.* 4:111–128, Jan. 1971.

[2] Bagdikian, Ben H., "A Forgotten New Deal Experiment in Land Reform in Mississippi," *I. F. Stone's Weekly* XV, No. 25: 3, July 31, 1967.

[3] Barraclough, Solon, *FAO/SIDA Symposium on Agricultural Institutions for Integrated Rural Development*, FAO, Rome, June 1971.

[4] Bertocci, Peter, "Patterns of Social Organization in Rural East Pakistan," in *Bengal East and West*, ed., A. Lipski, Michigan State University Asian Studies Center, Occasional Paper No. 13, South Asia Series, 1970, pp. 105–137.

[5] ———, "Social Stratification in Rural East Pakistan," Rochester, Michigan, Oakland University, March 1971, mimeo.

[6] Brown, Lester, *Seeds of Change*, New York, Frederick A. Praeger, Publishers, 1970.

[7] Brown, Murray, *On the Theory and Measurement of Technical Change*, Cambridge, Cambridge University Press, 1966.

[8] Burki, Shahid Javed, *Social Groups and Development: A Case Study of Pakistan*, Harvard University, Center for International Affairs, 1972 (forthcoming).

[9] Dorner, Peter, "Needed Redirections in Economic Analysis for Agricultural Development Policy," *Am. J. Agr. Econ.* 53:8–16, Feb. 1971.

[10] Faidley, Levern, and Merle Esmay, "Introduction and Use of Improved Rice Varieties: Who Benefits?" East Lansing, Michigan State University, Nov. 1970, mimeo.

[11] Falcon, Walter P., "The Green Revolution: Generations of Problems," *Am. J. Agr. Econ.* 52:698–710, Dec. 1970.

[12] Findley, R., and H. Grubert, "Factor Intensities, Technical Progress, and the Terms of Trade," *Oxford Economic Papers* 11:111–127, Feb. 1959.

[13] Forrester, Jay, *Principles of Systems*, Cambridge, MIT Press, 1967.

[14] Gardner, Bruce, "Distribution of Gains and Losses from Economic Growth in Rural Areas," in *Benefits and Burdens of Rural Development*, Iowa State University, Center for Agricultural and Economic Development, Iowa State University Press, 1970.

[15] Gotsch, Carl H., "Notes on the Current Status and Future Development of West Pakistan Agriculture," Paper presented at the Workshop on Rural Development in Pakistan, Michigan State University, July 1971.

[16] ———, "A Programming Approach to Some Agricultural Policy Problems in West Pakistan," *Pakistan Develop. Rev.* 8:192–225, Summer 1968. Revised and reprinted in Hollis B. Chenery, *et al.*, *Studies in Development Planning*, Cambridge, Harvard University Press, 1971.

[17] ———, "Technology, Prices and Incomes in West Pakistan Agriculture," Economic Development Report No. 199, Development Research Group, Center for International Affairs, Harvard University, Oct. 1971.

[18] Hardin, Lowell, "Later-Generation Agricultural Development Problems," in *Agricultural Development*, New York, Rockefeller Foundation, April 1969.

[19] Hayami, Yujiro, and Vernon Ruttan, *Agricultural Development*, Baltimore, The Johns Hopkins Press, 1971.

[20] Hicks, J. R., *The Theory of Wages*, London, The Macmillan Company, 1963.

[21] Johnston, Bruce F., and John Cownie, "The Seed-

Fertilizer Revolution and Labor Force Absorption," *Am. Econ. Rev.* 59:569–582, Sept. 1969.

[22] Kain, John, and Joseph Persky, "The North's Stake in Southern Rural Poverty," in *Rural Poverty in the United States*, President's National Advisory Commission on Rural Poverty, Washington, D. C., U.S. Government Printing Office, 1968, pp. 288–306.

[23] Kaneda, Hiromitsu, "Economic Implications of the 'Green Revolution' and the Strategy of Agricultural Development in West Pakistan," *Pakistan Develop. Rev.* 9:111–143, Summer 1969.

[24] Khan, Akhter Hamid, "Tour of Twenty Thanas," Comilla, Pakistan Academy for Rural Development, Feb. 1971.

[25] Ladejinsky, Wolf, "The Green Revolution in the Bihar-Kosi Area: A Field Trip," *Econ. & Polit. Weekly* 4:15–19, Sept. 27, 1969. As quoted in Martin Abel, "The Distribution of Agricultural Development Gains in India: A Case Study for South and Southeast Asia," *Staff Paper*, Department of Agricultural and Applied Economics, University of Minnesota, Nov. 1971.

[26] Lenski, Gerhard E., *Power and Privilege*, New York, McGraw-Hill Book Company, 1966.

[27] Marglin, Stephen A., "What Do Bosses Do? The Origins and Functions of Hierachy in Capitalist Production," Harvard Institute of Economic Research, Discussion Paper Series No. 222, Nov. 1971.

[28] Marx, Karl, *Capital*, Vol. I, New York, Random House (Modern Library), 1906.

[29] Meadows, Dennis, "The Predicament of Mankind," *The Futurist* 5:137–144, Aug. 1971.

[30] Mohammad, Ghulam, "Private Tubewell Development and Cropping Patterns in West Pakistan," *Pakistan Develop. Rev.* 5:1–53, Spring, 1965.

[31] Mosher, A. T., *Creating a Progressive Rural Structure*, New York, Agricultural Development Council, 1969.

[32] Naseem, Mohammad, *Small Farmers in the Agricultural Transformation of West Pakistan*, unpublished Ph.D. thesis, University of California, Davis, 1971.

[33] Pakistan, Government of, *Agricultural Census*, 1960.

[34] ———, "A Report on the Farm Mechanization Survey, 1968," Agricultural Census Organization, June 1969.

[35] Raper, Arthur, *et al.*, *Rural Development in Action, The Comprehensive Experiment at Comilla, East Pakistan*, Ithaca, Cornell University Press, 1970.

[36] Rochin, Refugio I., "The Impact of Dwarf Wheats on Farmers with Small Holdings in West Pakistan: Excerpts from Recent Studies," Ford Foundation, Islamabad, April 1971, mimeo.

[37] Ruttan, Vernon, "Agricultural Product and Factor Markets in Southeast Asia," Paper presented at the A/D/C—University of Kentucky Seminar on "Adapting Agricultural Cooperatives and Quasi-Cooperatives to the Market Structures and Conditions of Underdeveloped Areas," Lexington, Kentucky, April 1967.

[38] Schaffer, James D., "On Institutional Obsolescence and Innovation—Background for Professional Dialogue on Public Policy," *Am. J. Agr. Econ.* 51:245–267, May 1961.

[39] Schultz, T. W., "Institutions and the Rising Economic Value of Man," *Am. J. Agr. Econ.* 50:1113–1122, Dec. 1968.

[40] Smith, Douglas, "Technology and the Dynamics of Rural Class Differentiation in East Bengal," Center for Population Studies, Harvard University, July 1971.

[41] Solow, Robert, "Recent Developments in the Theory of Production," in *The Theory and Empirical Analysis of Production*, ed., Murray Brown, Studies in Income and Wealth No. 31, National Bureau of Economic Research, New York, Columbia University Press, 1967.

[42] Weber, Max, "Class, Status, Party," in *From Max Weber, Essays in Sociology*, eds., H. H. Gerth and C. Wright Mills, New York, Oxford University Press, 1946.

Income Maintenance Programs in the 1960's: A Survey

Emiel W. Owens

The nation's growing concern with poverty has directed our attention to the increased need for and importance of human resource development. Several different factors are responsible for society's concern and for redirecting and enlarging our initiatives:

1. Greater recognition of the need for higher levels of skills and training in order to reach the productivity levels required for higher income.
2. Urban unrest associated with poverty, racial discrimination, inadequate social, economic, and educational opportunities for minorities and other disadvantaged groups; among the other effects, this lack has been largely responsible for a national deficit in human capital formation among minorities and other disadvantaged groups.
3. The increasing reliance of social production processes (especially primary and secondary economic activities) upon scientific knowledge accentuates the effects of human capital deficiencies on disadvantaged individuals and groups.
4. Rapid rates of economic growth and technological change require a continuous reallocation of human resources, and further accentuate the effects of these deficiencies among the disadvantaged groups.

In the midst of the high level of economic activity witnessed during the 1960 decade some social welfare problems were recognized, even if unresolved in most cases; to mention a few:

1. Thousands of perennially unemployed or underemployed live in poverty in rural areas or central city ghettos.
2. Thousands of youth annually enter the labor force without the qualifications to obtain employment at socially acceptable levels of remuneration.
3. Negroes, Indians, and Appalachian and Ozark whites are below the national average in education and in health and above average in their share of substandard housing and social ills.
4. Millions of children are reared in poverty. Two results of growing up in the life style of poverty are high rates of cultural deprivation and mental retardation. Both of these are preventable conditions.
5. The delivery service systems of the new antipoverty programs are fragmented and not well-organized to assist the deprived and disadvantaged most in need of help.

The growing awareness of the pervasiveness of these conditions and their dehumanizing effects has called forth new public and private initiatives. Unfortunately, the growth in awareness has not been matched by a growth in an analytical understanding of root causes, although slow and painful progress has been made. It is now clear that much of the expenditure for education and health should be regarded as investments, and the level and direction of most of these expenditures should be firmly based on investment criteria. For this and other reasons the highlighting of poverty and racial problems has reinforced the principle idea that opportunity for full development of the individual is the foundation for both civil and social rights and genuine economic opportunity.

In this paper we examine poverty developments in the 1960's from two perspectives.

First, we are interested in the changes that took place in the magnitude, characteristics, and incidence of poverty as a result of poverty programs and the functioning of the economy during the decade. Program effects are of particular interest because the authorization under the Economic Opportunity Act of 1964 of the Office of Economic Opportunity (OEO) marked a change in the philosophy and magnitude of poverty programs. The new programs represented a movement away from categorical programs to relieve some of the harsher effects of poverty in target households in the direction of removing causes permanently, attempting among other objectives to break the intergenerational cycle of poverty.

Our *second* principal interest is in what we have learned from the experience in the 1960's. It is obvious that we must have learned from the different directions poverty programs took in the 1960's. The other, more important source

Emiel W. Owens *is associate professor of finance and research associate, Center for Human Resources, College of Business Administration, University of Houston.*

of basic knowledge about poverty was from social science research. The flow of research findings was increased considerably during the decade, partly in response to a need for evaluating poverty programs, partly as a result of a need for a better understanding of poverty problems. Much of what we have learned about poverty is due to the emergence of human capital during the decade as an active and rigorous field of economic research.

What We Did About Poverty

Federal support for the war on poverty has been siphoned through several programs: Social Security (that part of it reaching the poor or near-poor), welfare, nutrition, health, employment, education and youth, housing, and others. Federal expenditures in these program areas amounted to one-third of the federal cash payment budget and approximately 7 percent of the gross national product in 1968 [27, p. 68]. Recent budget messages from the President indicated that some 10 federal agencies would devote an estimated $29.7 billion in FY 1970, and $32.9 billion in FY 1971 to assist poor people [30, p. 29]. With the passage of the Economic Opportunity Act of 1964, program purposes have been focused on a wide range of poverty-related problems that had not previously been widely recognized or fully understood. Five categories of achievement can be examined.

Awareness and need

Poverty and dependence still exist in America. During the last 10 years, social scientists have continued to collect and disseminate a growing volume of statistics describing and dramatizing poverty. We have read about the plight of the urban and rural poor, the aged and the disadvantaged. Michael Harrington [10] has told us of *The Other America;* John K. Galbraith [9] has scolded us for the *Affluent Society*. Ministers have spoken out repeatedly about malnutrition, led civil right movements, and reacted to the "Secular City," while the average man on the street has been left baffled, first by his mounting taxes and then by statistics telling him that some 5.4 million American citizens still go to bed hungry each night. One of the major by-products of this intense campaign to focus the nation's attention upon poverty is an awareness on the part of the poor that they are poor and that poverty is not an acceptable condition.

The poor include those who have failed in their efforts to make a livelihood in our competitive society and a disproportionate number of Negroes, Indians, Spanish-Americans, and Appalachian and Ozark whites who have often been deprived of access to the opportunities that lead to fulfillment of the American dream. The real tragedy, however, lies in the disproportionate number of poverty family heads who for reasons of inadequate opportunity and preparation have never been able to get started or stand on their own feet in our society. A portion of the population large enough to constitute a medium-sized nation has been, and still is, excluded from full participation in our society [11, p. 1]. The tragedy of our waste in human resources increasingly makes clear how far we fall short of our central goal of being a democratic society characterized by equality of opportunity.

The needs of the poor have been identified in many studies. For many of the slum dwellers, the path to productivity has been closed off by poor health or by the lack of job opportunities, necessary skills, education, housing, community services, or protection from exploitation. Involuntary idleness turns many toward social aberrations. Agencies designed to meet the needs of the poor (i.e., local, state, and federal governments, private industry, and school districts) have too often had too little money and too short-lived an interest.

The existence of poverty

At the end of 1970 there were 25.5 million poor Americans as measured by the United States Social Security Administration (SSA) Poverty Definition [16, p. 3]. The poverty threshold is encountered when a nonfarm male-headed family of four earns an annual income of less than $3,553 per year, or $2.43 per person per day. Thirteen percent of the population lived below this very low poverty threshold in 1970 [31, p. 1].

Of the 25.5 million Americans in poverty in 1970, 10.7 million were under 18 years of age. This was approximately one-sixth of all the children under 18 [14, p. 12]. One-half of the children in poverty are in families with five or more children [14, p. 12]. An examination of the profile of the poor will show that more than 70 percent of the poor can be listed as [33, p. 3]:

a. Fifteen percent are 65 years old or older, having already passed the average age of

highest productivity. Aged family heads and unrelated individuals comprised approximately 19 percent of all poor white persons but only 7 percent of the Negro poor.

b. Forty-five percent are children under 18 years of age or those too young to join the labor force on a full-time basis. (Eighteen percent are children under 6 years of age.) Children under 18 years accounted for 36 percent of all white persons below the poverty level, compared to 54 percent of all Negroes who were poor.
c. Eight percent are women under 65 years old heading families, thus performing services for which no immediate cash income is forthcoming.
d. Some proportion of the remaining poor are prevented from obtaining sufficient labor income for a combination of reasons, such as poor health, lack of skill, and social discrimination which disqualifies them in the labor market.

Clearly, we can see that the aged poor, poor children, and mothers taking care of poor children constitute nearly three-fourths of the whole poverty group.

Declining poverty population, 1959 to 1970

The number of poor Americans declined during the 1960's, most dramatically in the 1964–69 period, with the total falling from 38.8 million in 1959 to 24.3 million in 1969 (Table 1). Poverty numbers increased by 1.2 million between 1969–70 or by 5.1 percent [28, p. 1].

The gross flow of households across the poverty line during this period was substantial, but the poverty problems tended to be persistent among certain subgroups of the population. The number of poor in families with female heads increased during this period, and the number of poor children in female-headed households increased by 35 percent. In 1970, persons in female-headed households constituted 14 percent of all persons but 44 percent of all poor persons [31, p. 6]. The unrelated individuals still may be the forgotten poor, as there was little change in their poverty status during the 1960 decade. The number of poor persons living on farms in the United States decreased from 4.4 million to 2.0 million, almost 55 percent, between 1964 and 1967.

Some of the decrease in numbers of farm poor was the result of a change in residential classification from farm to nonfarm. Although such a change would decrease the number of farm poor, it would not decrease the total number of poor. In contrast, two other sources, increasing the income that farm families receive from nonfarm employment and increasing income from farming, clearly resulted in a decrease in the total number of poor families.

Recent events have focused public attention on problems of race and race relations which are intertwined with poverty, unemployment, and alienation. An accurate measure of the help given by anti-poverty programs specifically to minority groups is difficult to obtain. Changes in the poverty and employment plight of the nation's largest minority group of more than 22 million Negroes had both positive and negative aspects during the 1960 decade. Most statistics reflect substantial economic gains. A general view of economic progress can be observed in Table 2. Gains made during the

Table 1. Percent changes in the number of poor persons between 1959 and 1968, by race, age, sex of family heads, and family status [7]

Category	All	Total white	Non-white (millions of persons)	Households all	Headed by male White	Headed by male Non-white	Households all	Headed by female White	Headed by female Non-white
		(Percent Change in the Numbers of Poor Persons)							
All Persons	−35.7	−38.9	−27.4	.48	−49	−48	0	−10	+21
Persons in families	−40.1	−44.6	−29.4	.50	−51	−49	0	−16	+24
Heads	−39.3	−41.5	−33.0	.49	−48	−52	− 8	−17	+ 7
Children 18	−37.6	−44.0	−25.0	.52	−52	−50	+ 6	−14	+35
Others	−45.7	−48.2	−37.0	.49	−51	−51	−13	−21	0
Unrelated individuals	− 4.7	− 4.8	− 4.7	−15	−14	−19	0	− 1	+ 6
Persons, 65 and over	−19.0	−20.0	−12.5						
Persons, 18–64	−39.0	−42.0	−32.0						

Table 2. The diminishing cost of being black [13]

Criteria	Earlier Status		Current Status	
1. Unemployment rate				
a. Overall	10.2%	(1960)	6.5%	(1969)
b. Teenage	30.4%	(1963)	24.4%	(1969)
2. Median family income				
a. Non-whites (in 1968 dollars)	$3,794	(1960)	$5,590	(1969)
b. Ratio of non-white to white	55%	(1960)	63%	(1968)
c. Ratio of blacks only to whites	54%	(1965)	60%	(1968)
3. Percent of families with incomes over $8,000 (in 1968 dollars)	15%	(1960)	32%	(1968)
4. Blacks below poverty level	55%	(1959)	35%	(1968)
5. Black occupancy of substandard housing units	44%	(1960)	24%	(1968)
6. Education: Negro men, 25–29, who completed four or more years of high school				
a. Percentage	36%	(1960)	60%	(1969)
b. Ratio of black to white	57%	(1960)	77%	(1969)

1960's seem impressive, but it is also worth noting that:

a. The black unemployment rate was as low as 4½ percent in 1953 compared with 7.3 percent today [13, p. 7].
b. While black teenage unemployment was cut by one-fifth from 1960–1968, white teenage unemployment dropped by one-third. Teenage female unemployment increased by 24 percent between 1960 and 1970.
c. Black Americans constitute one-ninth of our population but more than one-third live in poverty today [13, p. 7].

Education

The federal government through its "Head Start" and "Upward Bound" programs successfully established a healthy challenge to the "business as usual" approach that public school systems have held toward the plight of children of the poor. In 1968 more than 2 million children participated in summer Head Start programs and some 50,000 in the follow-through all-year program. Success of Head Start programs has led also to an increased public awareness of the educational needs of poor children and the increased support of the Elementary and Secondary Education Act enacted in 1965 [36, p. 61]. As a result of Upward Bound and other teenage programs designed to benefit needy but talented youngsters, colleges are opening their doors to new population groups to an extent never before experienced [36, p. 6].

During the five years since the passage of the National Defense Education Act, some $800 million have been paid in grants and loans to more than 500,000 students. Federal manpower training programs assisted some 1.3 million unemployed and underemployed persons obtain jobs. The median years of completed schooling increased substantially, from 10.3 in 1940 to 12.6 in 1969 for persons between 25 and 29 years of age. Among the non-white, where poverty tends to focus, the educational gains were substantial. In 1960, 36 percent of Negro males age 25–29 had completed four years of high school or more compared with 60 percent in 1969 [35, p. 6].

Housing

The quality of life in any community is first reflected in its attitude and emphasis on housing. The Housing Act of 1949 pledged "a decent home in a suitable living environment for every American family"—neither of these objectives has been reached. In 1950 there were 42.8 million homes and apartments in this nation, of which 15.2 million or 38 percent were substandard. In 1960 the percentage had declined to 16 percent and to 10 percent by 1966 [38, p. 18]. In 1950, 16 percent of the nation's housing was "overcrowded" or seriously overcrowded. By 1960 this percentage had declined to 12 percent.

Approximately 11½ million new housing units were started between 1960 and 1967, and the figures on the declining proportion of structurally unsound and overcrowded dwellings suggest that the new construction increased the supply of available housing. Residential construction starts and rehabilitations in fiscal year 1969 totaled 1.6 million units. Mobile home units constructed total 363,000 units [22, p. 84].

During the 1960's the federal government directly assisted low income families in residential construction and rehabilitation through a series of programs administered through the Department of Housing and Urban Development (HUD) and the Farmer's Home Administration (FHA). Below is a description of four major federal assistance programs [22, p. 87]:

a. Low-rent public housing. In 1969 federal contributions averaged $1,057 annually per unit of public housing.
b. Rent supplement. Federal expenditures for 1969 averaged $1,128 per unit.
c. Section 236 Rental Assistance. In 1969, federal expenditures averaged $804 per unit.
d. Farmer's Home Administration (FHA) insured loans.

The average size loan for 1969 was $9,866. In 1970, $784 million was loaned to 79,500 borrowers. The 1971 budget calls for $1.4 billion to be loaned to 143,500 borrowers. To overcome some handicaps experienced by the poor in efforts to secure housing the government has undertaken "Operation Breakthrough," designed to demonstrate feasibility of the high-volume housing technique and remove market constraints that inhibit their use.

Nutrition and health

There have been dramatic increases in health status and life expectancy over the past few decades. The expectancy of life at birth in the United States has increased from 47.3 years at the turn of the century to 70.5 years in 1967 [34, p. 12]. But why are we as a nation not as healthy as we could be? There is evidence which strongly suggests that social and economic deprivation and the uneven distribution of medical care are a large part of the problem. This is suggested by the finding of a report made by the National Food Consumption Survey that in 1955 approximately 25 percent of American families in poverty had diets seriously deficient in essential nutrients and that by 1965 the number had risen to 36 percent [15, p. 22]. The gap between the affluent and the very poor in America, the report stated, has widened, with the poor increasingly incapable of keeping pace with a rising cost of survival [15, p. 21]. In 1969 the death rates for black infants in our ghettos and rural slums were increasing [15, p. 33]. Additional years of life expected after 25 for black and white Americans in 1960 were 43.1 and 48.3, respectively, a difference of -5.2 years. By 1968 this disparity had widened to -6.0 years [32, p. 97]. In 1961, the public health service discovered "Kwasheorkor," a starvation disease, among the Navajo Indians on the Arizona Reservation. Eight years later in 1969 physicians at the same public health hospital reported they had treated 44 cases of "Kwasheorkor" among Indians on the reservation. The National Nutrition Survey in 1969 uncovered seven cases of starvation disease among the first 12,000 poor examined [15, p. 34]. The National Institute of Child Health and Human Welfare reported in 1969 that the chain of poverty is connected to mental retardation. A number of other studies have shown that a complex of factors in the culture of poverty appears to be linked to nonorganic retardation. Premature birth rate of the poor is three times that of the average American, and 50 percent of the premature-born infants grow to maturity with intellectual capacity significantly below normal [15, p. 38]. Children of the poor show impaired learning ability three to five times as often as other children. Five percent of the children in the United States are born mentally retarded, yet by the time they reach 12 years of age 11 percent are retarded, which indicates that we produce as much mental retardation as is born [15, p. 38].

The total cost of hunger malnutrition in American is incalculable. The ill-fed among 7 million poor American children constitute a danger to the nation, for they may never function in the labor market. About three Americans out of every 100 have an I. Q. below 70, the cut-off point for borderline intelligence, and estimates indicate that by 1970 the number of mentally retarded Americans will increase by about a million [17, p. 67]. It limits the potential of this entire nation.

Other achievements

Efforts by the OEO to help migrant and seasonal farm laborers throughout the United States have represented for these citizens one of the few real hopes of breaking the quasi-feudal system in which they have traditionally been caught. Title III of the Economic Opportunity Act includes financial assistance for migrants and other seasonal farm employees and their families. Projects include accelerated school programs to shorten the school year for children of migrants, adult education in literacy and other basic skills, remedial summer school programs for youth, vocation training for adults, and day care centers for pre-school children. An estimated 150,000 workers and their dependents had been served in 27 states under the program by the end of 1965 [26, p. 52]. In 1968, 250,000 migrants were reached.

The one-half million Indians in the United States are the most rural of all ethnic groups in the nation. Some of the most abject poverty anywhere in the United States is found among these Indian-Americans. For example, in 1960 70 percent of all Indian farm families had incomes under $3,000. The median annual income of all employed Indian farm males was just over $1,000 [16, p. 12]. The Office of Economic Opportunity has begun to break the structure of the economic and social power over the reser-

vation Indians, attempting to provide some opportunities for economic and social development. There is hope now that the Bureau of Indian Affairs will be forced to change some of its most degrading policies and programs and see the Indians as human beings capable of responsibility and self-determination.

Apathy, hopelessness, and frustration among the poor are the results of generations of poverty. But in some poverty programs, the attitude among some low income families that nothing can be done about economic and social ills has been replaced by a new awareness of community resources and a belief that living conditions can be altered and improved.

What We Have Learned

The severity of poverty

Statements concerning escape from poverty or decline in poverty numbers can be misleading, particularly when they fail to account for distances moved from an established criterion such as a poverty line or threshold. We know now that poverty is not a discrete condition, as there are no sharp lines separating the poor from the near-poor or nonpoor. Most programs focused specifically on alleviating poverty give a disproportionately large share of the benefits to the poor who need help least or to none of the poor. Between 1959 and 1968 there was an insignificant reduction in the percentage of poverty families with an income deficit of $500, but families with a deficit over $3,000 increased significantly (Table 3). Consequently, poverty is reduced more by adding to a family's income if the family is at 50 percent of the poverty threshold rather than at 75 percent of it. To reflect this concept, Watts [39, p. 326] proposed a poverty function that aggregates the logarithm (base e) of each family's welfare

Table 3. Percentage distribution of size of income deficit for families below the poverty level in 1968 and 1959, by race of head of household [31]

Size of income deficit	All races		White		Negroes and other non-white	
	1968	1959	1968	1959	1968	1959
$1– $499	26.8	27.0	29.7	30.1	19.6	18.4
$500– $999	23.5	25.3	24.7	36.8	20.5	20.7
$1000–$1999	28.0	30.7	26.2	29.4	32.7	34.3
$2000–$2999	13.5	11.6	12.3	9.7	16.9	17.2
$3000– over	8.1	5.4	7.2	4.0	10.2	9.4
Median income deficit	$993	$956	$907	$868	$1,260	$1,280

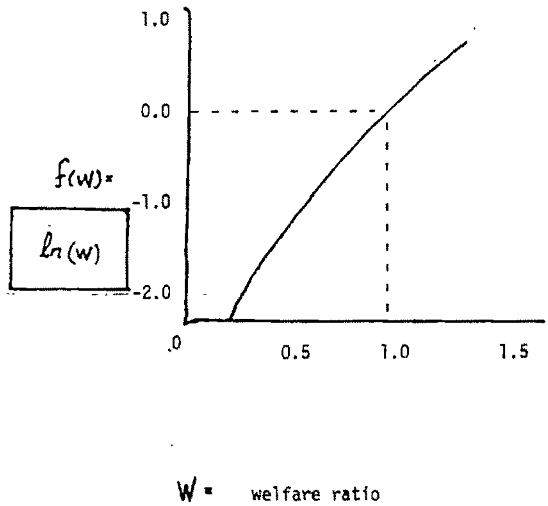

Figure 1. Logarithm function of welfare ratio for an individual poverty family. Source: [18, p. 327].

ratio, which is the ratio of a family's permanent income to the poverty threshold. This concept facilitates aggregation of detailed data into a one-dimensional measure of the nation's poverty problem.

Figure 1 illustrates the function for an individual family.

The aggregate poverty function is mathematically defined as

$$P = \sum_{i \in L} N_i \log W_i$$

where:

L = set of subscripts for families with $W \leq W^* \leq$ median W (W^* essentially represents the poverty threshold),
N_i = Size of ith family,
W_i = Welfare ratio of ith family.

For $W^* \leq 1$, $P < 0$; for $W^* > 1$, P could be positive.

But, in looking at the profile of the poor, we know also that it is entirely possible for a family's measured income to be zero in the complete absence of anti-poverty measures. This raises difficulty with the use of Watts' welfare ratio if related to a family's measured income, since his welfare ratio was defined in terms of a permanent family income. To avoid such difficulty, a different function of the welfare ratio is proposed:

$$F(W') = e^{-W'}$$

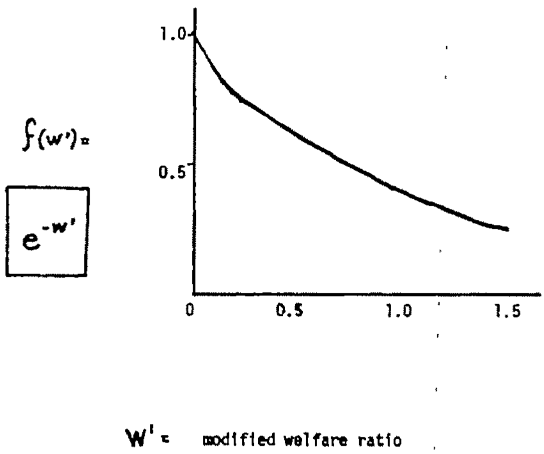

Figure 2. Modified logarithm function of welfare ratio for an individual poverty family.

where:

W' = ratio of measured income to the poverty threshold,

e = base of natural logarithm = 2.718.

Graphically, the proposed function is depicted in Figure 2. The use of the negative exponential function retains Watts' point of view that poverty becomes increasingly more severe at lower values of the welfare ratio. However, it substitutes a positive function for one that is negative in the critical area: $W' \leq 1$. Mathematically, the aggregate poverty function would then be

$$P' = \sum_{i \in L} N_i e^{-W_i'}$$

where:

W_i' = modified welfare ratio (using measured income) of ith family, and L and N_i are the same as previously defined.

P' is positive for all finite values of W_i'. The lower P', the less severe the poverty; conversely, when poverty is reduced, so is P'.

Distance from the poverty line has proved quite significant as a determinant of poverty flows; of those families leaving poverty between 1965 and 1966, one-fourth remained within $500 of the poverty threshold. Those families falling into poverty fell relatively deeply; more than 55 percent of the new poor fell more than $500 into poverty [16, p. 27]. In 1970 it would have required almost $11.4 billion to raise above the poverty level the income of families and unrelated individuals who were below [37, p. 60]. Many of those who rose out of yesterday's stock poverty entered the areas above subsistence but below present-day standard of healthful, decent living.

The 1960's were years in which there was a relative deterioration in the quality of life among the poorest of the poor as measured by the increasing concentration of poor families with income deficits greater than $3,000.

Induced dependence

Social paternalism as a way of dealing with poverty has perpetuated dependence and patronization of the poor. This has been and continues to be a costly failure. By any standard of comparison, the decade of the 1960's was one of unprecedented prosperity. Per capita disposable income in constant dollars rose by more than 25 percent, while unemployment fell from an average of nearly 6 percent of the labor force in the early 1960's to considerably below 4 percent at the end [12, p. 2]. Perhaps even more significant, the median earnings of non-white families increased from only 54 percent of white families to 61 percent—still a great disparity but an improvement.

In spite of these apparent economic advances, the number of dependent individuals or those on "welfare" increased from less than 7 million or 3.8 percent of the total population at the beginning of the decade, to more than 9 million or 4.8 percent of the total population in the early 1970's [12, p. 4]. The number of case loads concerned with Aid to Families with Dependent Children increased 60 percent from 3½ million in 1960 to 6½ million in 1970 [12, p. 4].

Corollary with this increased ratio of dependence, other variations in family structure took place. Some noteworthy changes were [31, p. 5]:

a. The number of poor families headed by year-round full-time workers declined by 50 percent.
b. Poor families whose heads were not in the labor force increased from 39 percent to 49 percent of all poor families.
c. The proportion of poor family heads reporting work experience during the year declined from 75 percent to 68 percent.
d. Black families headed by women accounted for about half the increase in the number of black families during the 1960's. The percentage change experienced

by those families headed by a female was greater than for husband-wife families [32, p. 31].

The question could be raised: What factor gave rise to this paradoxical increased dependence and change in family composition during a period of general prosperity? First, prosperity itself could have been partly responsible as it provided the vehicle for low-income rural families to migrate from their impoverished and sometimes hostile rural environment to urban centers to seek a better life. Some 7 million migrants left the farm destined primarily for urban centers during the 1960's [12, p. 2]. Second, work experience could have been a factor. Let's look at the linkage between the work experience of the poor and dependence, as a lack of participation in the labor force is often spotlighted as one of the more important features of poverty. In 1968, of the 3.3 million male-headed families in poverty, 1.1 million or one out of three heads had full-time jobs at which they worked from 50 to 52 weeks per year without escaping poverty [36, p. 121]. Of the 1.8 million female poverty family heads, 12 percent worked full-time and remained in poverty.

These working experiences provide documentation of the inability of the working poor to alter substantially their plight with their own efforts. Some family heads found it advantageous to separate to allow their families to qualify for higher levels of income assistance, thereafter becoming hopelessly dependent on the public for survival. Two findings from a recent study support the hypothesis that some poverty programs offer low income parents strong financial incentives to separate, namely:

a. In a sample of welfare mothers in New York City, nearly 60 percent of those mothers who were separated or divorced were separated or divorced after they went on welfare [3, p. 93].
b. The number of families headed by females in the cities increased by 660,000 from 1960 to 1968 [3, p. 42]. The rate of increase was greatest among those most eligible for welfare. Nearly two-thirds of all children in urban Negro families having incomes of less than $4,000 are now without fathers [3, p. 93].

Economic discrimination

The existence of racial bias and other practices of discrimination in a society reduce the effectiveness of programs directed toward the alleviation of poverty. The problems of poverty among Negroes are reinforced and complicated by the legacies of past discrimination and the effect of the discrimination that still remains in force.

Findings indicate that much of the apparent gain on white family income by black families during the period of 1950 to 1966 can be attributed to the higher total earnings that resulted from increases in the labor force participation rates of black females, rather than to any upgrading of occupations and earnings among black males [2, p. 405]. The narrowing of the black-white income gap between 1959 and 1969 was true only for black families where both husband and wife worked, where black family income was 99 percent of white in 1969 compared with 85 percent in 1959 [32, p. 31]. In young husband-wife families where only the husband worked, the ratio of median income of black to white was 71 percent in 1969 compared with 75 percent in 1959 [32, p. 31].

Table 4 shows that in the labor market the black female earns a higher return on additional education than the black male or white female at most comparable educational levels. In spite of this higher marginal increment to education for the black female, the income of the average

Table 4. Elasticity coefficient of education and income by age, sex and race, 1969 [32]

	Black male		White Male		Black Female		White Female	
	Income	Elasticity coefficient (EC)	Income	Elasticity coefficient (EC)	Income	Elasticity coefficient (EC)	Income	Elasticity coefficient (EC)
<8 years	$3,922		$5,509		$1,195		$1,303	
8 years	4,472	.04	7,018	.07	1,320	.03	1,688	.07
9–11 years	5,327	.10	7,812	.06	2,268	.36	2,356	.20
12 years	6,192	.08	8,829	.07	3,257	.22	3,234	.19
13–15 years	7,427	.09	9,831	.06	4,247	.15	3,427	.03
≥16 years	8,669	.08	12,354	.13	6,742	.29	5,707	.33

Table 5. Influence of the number of wage earners on family income by race [32]

Number wage earners	Median annual income		Marginal increment	
	Black	White	Black	White
0	$2,162	$3,183		
1	4,416	8,450	1.04	1.65
2	7,982	10,885	.76	.28
3	9,027	13,978	.16	.29
4 or more	11,259	16,248	.25	.16

black family with three earners in 1969 was not significantly different from the average white family with one earner (Table 5).

In observing the marginal increment over previous black workers, expressed as a percentage of the previous black worker's income for black and white families in Table 5, you will note that the second wage earner in black families gives the highest income increment, while the first wage earner among white families provides the largest increment.

As much as one-half of the income differentials between white and black workers during the 1960's was the lagged effect of discrimination that took place before 1960, principally in the form of opportunities for education and training and for valuable work experience [19, p. 485]. These "lagged" components of the differentials can be expected to persist over time even if market discrimination against black workers fell to zero [19, p. 475].

The $1,000 annual cost of being black in Table 6 is a *ceteris paribus* number. Other things being equal, it says that if Negroes had the same educational attainment, occupational composition, and geographic distribution as whites, they would still earn $1,000 a year less per person than whites. This residual means that two-fifths of the black-white income gap ($2,850 in 1960, the year Siegel made this calculation) represent the cost of discrimination after all elements of differences other than skin color have been removed.

Duncan [8] shows a similar proportion representing income discrimination. Starting with a total gap of $3,790 between black and white income, he accounts for $1,010 by differences in family background, $520 by difference in educational attainment, and $830 by occupational discrimination. After further adjustment, this leaves $1,200 to $1,400 as the cost of being black [8, p. 22].

The 30-year lag in black income distribution is another index of how far the Negro has been left behind [24, p. 22]. In 1965 the mean non-white family income was only slightly larger than the 1929 average income for both white and non-white. While the black income distribution has evolved from a steeply falling curve in 1947 into something closer to the familiar bell shape by 1965 (both in 1959 dollars), the bell is far less pronounced than for whites. By the mid-Sixties, it had reached a slope similar to that for whites 30 years ago [24, p. 22].

The need for specific government programs to alter the income distribution is emphasized by the lack of progress in eliminating discrimination. In the post-war period the median family income of non-whites has been stable at 55 percent (+4 or 5 percent) of that of whites, with a slight increase occurring in 1966–67 [24, p. 24]. Based on relative income measures, discrimination has changed little over the past decade, and on the basis of absolute measures, the discrimination gap has widened. If the median family income is used as a barometer for the widening discrimination gap, the difference between white and non-white median family income in 1947 was $2,302 (in 1967 dollars), but this difference had expanded to $3,033 by mid-1970 [29, p. 6]. This implies a growing disparity between whites and non-whites with respect to the amount of "dis-

Table 6. High cost of being black

Criteria	White	Black
1. Unemployment rates		
a. Overall (2nd Quarter) 1971 [28]	5.5%	9.9%
b. Teenage (2nd Quarter) 1971 [28]	14.9%	32.1%
2. Median family income—1970 [29]	$ 9,096	$ 5,538 (61.0%)
3. Dollar gap between white & black family income [16]	1947 X	X minus $ 2,302
	1960 X	X minus $ 2,957
	1967 X	X minus $ 3,133
4. Persons below poverty level—1970 [28]		
a. In percent of group	9.9%	33.6%
b. In millions	17,480	7,650
c. Worked 50–52 weeks	3.1%	12.0%
d. Were not in labor force	23.1%	60.6%
5. Persons 25 and over with less than eight years of schooling—1970 [28]	21.0%	40.3%
6. Occupants of substandard housing unit, 1968 [13]	6.0%	24.0%
7. Annual cost of being black [22]	X	X minus $ 1,000
8. Human capital cost of being black [3]	X	X minus $10,000
9. Distributional cost of being non-white [13]	X	X minus 30 Yrs.

cretionary" income available for the purchase of goods and services other than the basic necessities of food, clothing, shelter, and transportation.

Regional differences

Labor market discrimination is strongly associated with economic growth in both the South and non-South, but the regional relationship is different; in fact, it is just the opposite [21, p. 204]. In the South a rapid rate of economic growth is coupled with low levels of economic discrimination, but in the non-South a rapid rate of economic growth led to high levels of economic discrimination [21, p. 204]. Labor market discrimination then in the South is expressed in the form of wage discrimination, while in the non-South it is expressed in the form of hiring and upgrading practices.

Anderson [1], Tobin [25], and Brimmer [6] support the hypothesis that "the pace of Negro economic progress is particularly sensitive to general economic growth." Tobin cites the estimate that general economic progress would in 10 years diminish the prevalence of poverty by at least five percentage points [25, p. 90]. Brimmer foresees in the decade of the Seventies a 50 percent gain in per capita income for blacks against 40 percent for whites, noting that while expansion of the national economy is expected to be the mainspring of this improvement, continued advances in education will also play a major part [6, p. 3]. Anderson's study concluded that a 5 percent growth in national per capita income produces a $7\frac{1}{2}$ percent growth in non-white incomes, while stationary per capita incomes lead to a drop of $\frac{1}{2}$ percent a year in non-white income [1].

Human capital deficit

Today we know that human capital, the skills and knowledge embodied in the individual, is one of the critical determinants of per capita lifetime earnings. Individuals without the opportunity to obtain an adequate education or to acquire training and necessary skills have low marginal productivity and their earnings are usually below the poverty level. We also know now that one reason for the large differences in earnings between different ethnic groups in our society is the variation in the human capital invested.

For example, utilizing 1960 census data to estimate the value of stock in human capital invested in the average adult male, results showed an approximate $10,000 deficit investment in the Negro adult male compared with the average invested in white adult males [5, p. 2]. This difference was based on the average gap between investment in adult Negro and white males in education and work experience. The education and income variables were then used to capitalize the value of work experience for white and Negro males age 25 and over. The weighted average capital value of work experience in 1960 was $13,912 for whites and $4,049 for Negroes, a difference of $9,863 (Fig. 3). In estimating the capital investment in work experience and education for male workers, findings show that Negroes tend to receive less benefits from experience early in their working careers and their human capital begins to depreciate sooner than white workers [24, p. 7]. This is because of differences in income elasticity between the two groups with respect to the education and experience variables. The marginal value of education is also less at higher levels of schooling for Negroes. For example, in the Texas study of the rural poor, the income elasticities of education for family heads were: 0–1.9 years, .13; 2–3.9 years, .14; 4–5.9 years, .17; 6–7.9 years, .05; 8–9.9 years, .08; and 10–12 years, .007 [20, p. 12]. The national income

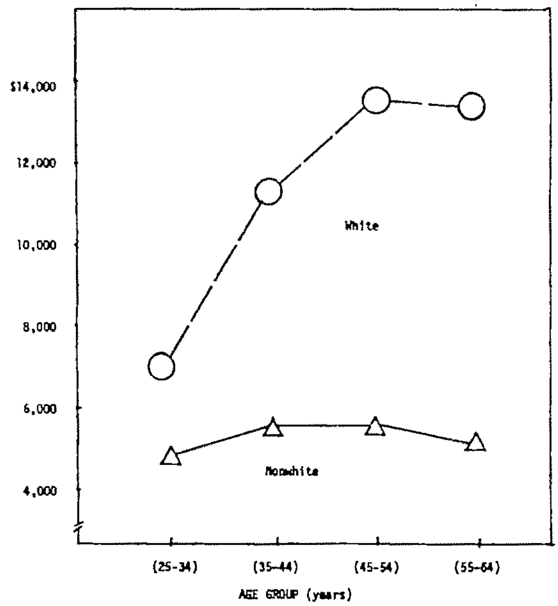

Figure 3. Incomes of white and non-white male college graduates 25–64 years old in the experienced labor force (1960). Source: [5].

elasticity figures for white males were 0.11 for elementary school, 0.72 for high school, and 1.73 for more than 12 years of schooling [24, p. 76]. The observation of particular significance is that as the educational levels rise and work experience increases, the income gap between white and non-white tends to grow and at an increasing rate with higher levels of education. The paradox of the whole education and experience function is that discrimination hurts the better educated non-white more than the less educated.

Sectional variations (North versus South)

Returns from capital investment in education and work experience also tended to be linked to sections of the country. For example, studies show the marginal returns to education were higher in the South than the North, but average incomes were higher in the North. This means that a higher shift coefficient and a greater return to experience in the North is more than offset by the differences in higher marginal returns to education in the South. The end result is a higher propensity for non-whites to migrate north to benefit from higher shift coefficients and more extensive or higher priced training than that of whites [22, p. 22]. It was also of interest to note that as educational attainment rises, the income gap between the North and South shrinks, but the gap between whites and non-whites widens. At the same time, as work experience increases, the income gaps between both North and South and white and non-whites widen. This means that the income differences produced by education are not much larger than those produced by experience. These results show that rates of return to investment in education and work experiences are a function of race and region of the country.

Farm and non-farm

The drama and conflict of urban poverty became a focal point during the decade of the 1960's, but for the most part, the plight of the rural poor went unnoticed. Yet, as the 1969 Manpower Report of the President pointed out, about 11 million rural Americans (one out of five) lived in poverty in 1966 [36, p. 21]. Rural residents, the report noted, "earn lower wages, lose more time because of ill health, are more likely to be unemployed or underemployed." But the urbanization of America and the job market has in cases undermined the economic position of many rural inhabitants and intensified the rural poverty problem. From 1950 to 1967, the number of farm jobs in the United States dropped by more than one-half, from 9.9 to 4.9 million [36, p. 21]. Other sources of rural employment also declined, such as mining employment, which was 901,000 in 1950 and shrunk to 616,000 17 years later. Despite these declines in the number of jobs, the size of the rural population has remained about the same, 54.5 million in 1950 and 53.8 million in 1970, a reduction of only approximately 1 percent [36, p. 21]. The total number of farms in 1968 was 3.1 million, a decline of 23 percent since 1960.

Rural black poor

By the end of the 1960's, the poverty plight of the rural black poor remained about as acute as ever. While mechanization continued to diminish the number of agricultural-oriented jobs, the persistent problems of substandard housing, malnutrition, inadequate training facilities, and social discrimination were as unresolved for them as they were three decades ago. The first obvious finding in the study of the rural poor in Texas was that poverty programs have been least effective in changing the economic plight of these Americans [20, p. 15]. Only a few material things were found which made it possible to distinguish their present-day life style from those of their remote ancestors. For example, one family out of three still had no means of transportation; one out of two no running water, two out of three no bath or shower, one out of two no kitchen sink [20, p. 14]. The annual cash family income of some 30 percent of the sampled families was less than $2,000, equating the average American family earning for 12 weeks. In 1969 the median income of nonfarm blacks was more than double that of blacks living on farms. Perhaps the most eloquent testimony of the barrenness of the lives under which the black rural poor lives is the number of their offspring who migrate annually—some 140,000. The black farm population declined by 50 percent during the 1960's, numbering less than one million in 1970. In 1950 there were approximately 560,000 black farm operators in this country; about 100,000 remained in 1970 [4]. The annual migration rate is insignificantly lower today than during the great migration flows following the world wars. Those that are left in the rural area are, by and large, the ones with the least adaptability to change: the elderly, the sick,

the illiterate, the fearful, and the unskilled. This is the paradox of the poverty rural programs during the 1960's; their focus for change and improvements bypassed those who were most in need of change.

Institutional failures

Another reason for the failure of existing institutional arrangements to solve the poverty problem in today's society is the failure to recognize that poverty itself has come to mean something quite different in the 1960's. Prior to this decade, poverty generally was felt to be a personal phenomenon, affecting individuals more than the collective of society. The wealth of the non-poor was directly related to the poverty of others, and poverty was the by-product of a lack of job opportunity, poor health, or low wage jobs. Wealth was then created through production, with wages and profits being inversely related. Theobold [23] in his book *The Challenge to Abundance* challenged the assumption upon which historically has hinged the relationship between increasing production and increasing national wealth. Theobold's point was that the wealth of a nation has shifted from a dependence on the role of producers to a dependence on the role of consumers. In a society of abundance and affluence, which for decades has not utilized its full productive capacity, an increase in consumption leads to an increase in national wealth and thereby an increase in the level of living.

In the 1960's it was found that even with the bolstering of the consumption capacity of a growing population, we still needed to increase our per capita consumption. The fiscal device of tax reduction is an example of possible action to meet this need. It is difficult, however, to accomplish this desired increased consumption capacity when some 25 million persons in society are subsisting on marginal incomes, limiting even their capacities to consume.

Summary and Conclusions

The war against poverty remains one of the most important domestic issues in America today. Anti-poverty programs have made progress in alleviating conditions associated with poverty, but by and large, these programs have not achieved substantive and lasting reductions in the effects of poverty. Poverty exists in rural and urban communities alike. The Gross National Product and the average level of living rose significantly during the 1960's. Great inequalities in the personal distribution of national output remain. One cannot ignore those residuals—two-fifths in the Siegal numbers, three-eighths in the Duncan numbers, and Thurow [24] lists it at one-third to one-half of the differentials between black and white income—which cannot be explained in terms of any deficiency that can be removed by purely economic measures, i.e., by investment in education, training, job experience, health, housing, and the like. It is that inescapable discrimination quotient which requires changes in the attitude and *ethnic* composition of the white community. Even if the pure "efficiency" measures could bring black income up to 80 percent of that of the white, the last 20 percent would depend on the removal of the social distance between black and white. According to present-day values and definitions, it could be said that "poverty won the war of the 1960's." But what lessons have we learned from the past programs that may be of value in guiding future policy?

A few major points will be mentioned.

a. To consolidate and continue the economic gains made on the poverty front during the 1960's requires a high level of employment and economic activity. This is because the poor tend to bear a proportionately larger share of the social costs associated with high rates of unemployment.
b. Future gains on the poverty front will have to be sought through both structural and distributive measures, i.e., measures to raise productivity through education, training, and on-the-job experience, to reduce discrimination, and to put a floor under income transfers. The well-being of a great many of today's poor can be improved only through some system of transfer payments.
c. Greater efforts must be made after training the poor to increase their access to jobs through provisions of moderately priced housing, the elimination of housing discrimination, and improvement of public transportation. Programs which improve mobility are preferable to those which subsidize immobility.
d. To be effective, economic anti-poverty programs need to be supplemented by anti-discrimination programs, and these

combined programs focus on minority poverty. The remedy for prejudice and bigotry is acceptance, and programs of acceptance as well as of investment are required. Examples of programs of acceptance include open housing, integrated schools, integrated employment, and, in general, sharing of the life space.

e. Implementation of combined investment and acceptance programs would constitute a major step in the direction of increasing investment in human resources and also fully accepting all citizens as Americans.

Policy Implications

The fiscal requirement involved in abolishing poverty in America is the least troublesome aspect of the problem. As it becomes more possible to eliminate the causes of poverty, the whole discussion of incentive versus adequacy becomes less serious. Findings presented earlier in this article reinforce the contention that a major objective of national policy should be a shift from short-run alleviation of poverty to a long-run set of programs that will eliminate dependency. The priority that has been given to increasing this nation's economic growth rate makes it even more important that public policy focus on making individuals more productive and less dependent. If factors that determine family economic status are subject to change, then raising of substandard incomes through public policy and programs appears possible. A nation that does not not make energetic and effective thrusts against poverty and its ghettos is in danger of having ghettos change the essential character of its life. A free society is dependent upon the action of responsible individuals. Yet a society cannot be free with huge numbers of poor. Poor people are powerless people and the people who are powerless do not have the opportunity to be responsible. Hope is beyond their understanding. From decision making based upon alternative choices comes the process of acquiring responsibility. This choice is basic to the preservation of a free society and the elimination of poverty.

References

[1] ANDERSON, W. H. LOCKE, "Trickling Down: The Relationship Between Economic Growth and the Extent of Poverty Among American Families," *Quart. J. Econ.* 77:511–520, Nov. 1964.

[2] ASHENFELTER, ORLEY, "Changes in the Labor Market Discrimination Over Time," *J. Human Res.* 5:403–430, Fall 1970.

[3] BANFIELD, EDWARD, C., "Welfare: A Crisis Without Solution," *The Public Interest*, No. 16, Summer 1969.

[4] BEALE, CALVIN L., "Rural Urban Migration of Blacks: Past and Future," *Am. J. Agr. Econ.* 53:302–307, May 1971.

[5] BERGMANN, BARBARA, "Investment in the Human Resources of Negroes," in *Federal Program for the Development of Human Resources, Vol. I, Part II, Manpower and Education*, U.S. Congress, Joint Economic Committee, Washington, 1968.

[6] BRIMMER, ANDREW F., "The Black Revolution and the Economic Future of Negroes in the United States," address at Tennessee State University, June 8, 1969, mimeo.

[7] Committee for Economic Development, *Improving the Public Welfare System*, New York, April 1970, Fig. 3.

[8] DUNCAN, OTIS DUDLEY, "Inheritance of Poverty or Inheritance of Race?" in *I. On Understanding Poverty; Perspectives from the Social Sciences*, ed., Daniel P. Moynihan, New York, Basic Books, Inc., 1969.

[9] GALBRAITH, JOHN K., *The Affluent Society*, 2nd ed., Boston, Houghton Mifflin Co., 1969.

[10] HARRINGTON, MICHAEL, *The Other America: Poverty in the United States*, New York, The Macmillan Company, 1963.

[11] HAUSER, PHILIP, "Twentieth Century National Goals in the Development of Human Resources," National Health Forum, University of Chicago, March 20, 1967.

[12] HEILBRONER, ROBERT, "The Economic Problem," *Newsletter*, Vol. 1, No. 2, Spring 1970.

[13] HELLER, WALTER, "Economics of the Race Problems," Lecture presented at the New School of Social Research, New York, March 1970.

[14] KAHN, ALFRED, J., "Poverty, Welfare and Public Policy," Conference on Income Maintenance, Macalester College, St. Paul, Minn., Nov. 1969.

[15] KAIN, JOHN, "Race and Poverty," in *The Economics of Discrimination*, Englewood Cliffs, N.J., Prentice-Hall, Inc., 1969.

[16] KELLY, TERRENCE, F., "Factors Affecting Poverty: A Gross Flow Analysis," in *Technical Studies*, Report of the President's Commission on Income Maintenance Programs, Washington, U.S. Government Printing Office, 1970, p. 1–82.

[17] KEYSERLING, LEON H., "Progress or Poverty," Conference on Economic Progress, Washington, Dec. 1964.

[18] MOYNIHAN, DANIEL P., ed., with assistance of CORINNE SAPOSS SCHELLING, *I. On Understanding Poverty; Perspectives from the Social Sciences*, New York, Basic Books, Inc., 1969.

[19] O'NEILL, DAVE M., "The Effect of Discrimination on Earnings: Evidence from Military Test Score Results," *J. Human Res.* 5:475–486, Fall 1970.

[20] OWENS, EMIEL, ALICE STUBBS, AND BORDEN NELSON, *The Rural Poor*, Texas Agricultural Experiment Station, to be published.

[21] RAYMOND, RICHARD, "Regional Difference in Racial Discrimination in Education and Employment," *Western Econ. J.* 8:190–208, June 1970.

[22] SEIGEL, PAUL M., "On the Cost of Being a Negro," *Sociological Inquiry*, Vol. 35, Winter 1965.

[23] THEOBOLD, ROBERT, *The Challenge of Abundance*, Patterson, N.Y., Clarkson N. Robert Publishing Company, 1961.

[24] THUROW, LESTER C., *Poverty and Discrimination*, Washington, The Brookings Institution, 1969.

[25] TOBIN, JAMES, "On Improving the Economic Status of the Negro," *Daedalus*, Fall 1965.

[26] TWEETEN, LUTHER, *Rural Poverty, Incidence, Causes and Cures*, Oklahoma State University, Department of Agricultural Economics, Processed Series P-590, July 1968.

[27] U.S. Department of Agriculture, ERS, Economic Development Division, *Rural Development Background Information*, Washington, 1969.

[28] U.S. Department of Commerce, Bureau of the Census, *Current Population Reports*, Series P-60, No. 77, May 7, 1971.

[29] ———, *Current Population Reports*, Series P-60, No. 78, May 20, 1971.

[30] ———, "Income in 1968 of Families and Persons in the United States," *Current Population Reports*, Series P-60, No. 66, Dec. 23, 1969.

[31] ———, "Poverty in the United States, 1959–1968," *Current Population Reports*, Series P-60, No. 68, Dec. 31, 1969.

[32] ———, "The Social and Economic Status of Negroes in the United States, 1970," *Current Population Reports*, Series P-23, No. 38, July 1971.

[33] ———, "Supplementary Report on Income in 1967 of Families and Persons in the United States," *Current Population Reports*, Series P-60, No. 64, Oct. 6, 1969.

[34] U.S. Department of Health, Education, and Welfare, *Toward A Social Report*, Washington, U.S. Government Printing Office, 1969.

[35] U.S. Department of Labor, Bureau of Labor Statistics, "Perspectives on Poverty," *Monthly Labor Rev.*, Feb. 1969.

[36] U.S. Department of Labor, *Manpower Report of the President, Report of Manpower Requirements, Resources, Utilization and Training*, Washington, March 1970.

[37] U.S. President, *The Budget in Brief*, Fiscal Year 1971, Washington, Bureau of the Budget, Feb. 1970.

[38] ———, *Economic Report of the President with the Annual Report of the Council of Economic Advisors*, Washington, U.S. Government Printing Office, 1970.

[39] WATTS, HAROLD, "An Economic Definition of Poverty," in *I. On Understanding Poverty; Perspectives from the Social Sciences* ed., Daniel P. Moynihan, New York, Basic Books, Inc., 1969.

Discussion: WILLIAM B. BACK, *USDA*

Gotsch introduced his paper by identifying some of the significant issues about distributive effects of farm technological change. Many more issues are relevant. Unfortunately, many of the major questions of interest were lost when he chose to take a microscopic view of some relationships among technology, institutions, and people within communities, primarily in Pakistan. My remarks will be directed mainly to identifying some of the elements of a broader perspective of how technical change affects income distribution within countries and how these distributive effects differ among countries.

Whereas Gotsch seems to emphasize distributive effects within populations of landowners in communities, I suggest the need for inclusion of tenants, sharecroppers, and laborers in populations of interest. This would encompass all recipients of land or labor income from farming. I believe it is important to keep distinguished land and labor income in an analysis of the income effects of technical change. Some variables and conditions affecting distribution of the effects of technical advance among and within these population groups are (1) distribution of rights to land income, or [as a proxy] the size distribution of land holdings, (2) tenure arrangements, (3) nonfarm employment opportunities of farm laborers, (4) attributes of the land market, and (5) governmental policies or programs affecting product prices, production, land income, wages, or rental arrangements.

The initial distribution of rights to land income may be the major factor governing the distributive effects of technical change within the farm sector of any country. However, countries with abundant nonfarm employment opportunities and with growth occurring in these opportunities will experience distributive effects less adverse to labor than in cases of countries without these conditions. For example, in the United States many farm workers actually experienced a gain in welfare by shifting to nonfarm work concurrently with technical change in agriculture. Others remaining in agriculture experienced a wide range in effects —some gained, some lost. This is not to say, however, that all migrants from farms to cities improved their lot, or that all departures from our farms occurred as a result of farm technological advance. Nevertheless, our existing levels of rural poverty, as well as our existing levels of rural affluence, have connections to both farm technological advance and to the form to urban migration.

One could hypothesize that labor-saving technology in most underdeveloped countries would have a more dramatic impact on the dis-

tribution of income within the farm sector than in the case of developed countries. Underdeveloped countries provide less opportunity than developed countries for farm workers to escape any adverse effects of technical change by shifting to nonfarm occupations. Such technology increases the ratio of land to labor income, and the initially higher degree of concentration of land ownership in most underdeveloped than in developed countries would have an accentutating distributive role. Also, such concentration of wealth is associated with institutional conditions in the underdeveloped countries consistent with maintenance of farm workers at the bare subsistence level. In addition, where land ownership is more concentrated, technical change occurs more unevenly among the farms, with the lagging smaller farms receiving few, if any, of the benefits of this advance.

Further assessment of the comparative distributive effects of technical change among countries will require consideration of demographic factors and farm prices. One problem suggested here is to ascertain whether increases in output of food result in corresponding increases in population, especially in underdeveloped countries.

It frequently is supposed that many underdeveloped countries experience a food problem, in contrast with a farm problem, and that green revolutions can only increase welfare within these countries as the food problem is being resolved. If the demand and supply conditions for food are this way, technical change which increases output more rapidly than the population increase could dampen or deter rising food prices rather than depress these prices. Either rising or falling food prices would have distributive effects within the farm sector independently of any technical change. Thus, to gain a perspective of the distributive effect of technical change, consideration must be taken of product price and income distribution changes, with and without this technical advance. It is all very complicated as a conceptual or empirical problem. Any governmental policies relating to farm production and prices add to the complexity.

The main point I am trying to make is that a broader perspective than taken by Gotsch is needed for ascertaining distributive effects of technical advance within countries, or comparison of these effects among countries. This is a subject containing many more questions than verified answers.

The printed program gave me the impression that the planners of this session expected Owens to evaluate the poverty programs of the 1960's, especially in reference to rural poverty. He presented an interesting paper on a slightly different subject, although he did include a bit on what I interpret to be the intended subject. I expected less emphasis on statistics of the general poverty situation, more evaluation of programs, and a sharper focus on rural poverty than was contained in the paper.

Reports [3] of a national advisory commission on rural poverty released in 1967 indicated the existence of a major amount of discrimination against the rural poor in delivery of services of poverty and other programs. According to these reports, poverty in rural areas also is at a higher incidence and severity than in urban areas.[1] Some updated comparisons of this kind by Owens would have been of interest.

Recent Presidential reports [4] to the Congress in response to provisions of Title IX of the Agricultural Act of 1970 indicate rural people are shortchanged on those programs with the most potential for alleviating the conditions associated with rural poverty—especially on such human resource programs as education, health facilities and services, manpower services, and welfare. Rural people also still receive less than their proportionate share of outlays for OEO programs. Apparently the systems for delivery of technical agricultural and farm program services to rural areas are efficient only for these purposes, and these systems are not being used as models of methods for delivering other program services to rural people. However, some experimental efforts are in progress to utilize the agricultural delivery systems in getting other governmental services to rural people, especially manpower services. Results thus far provide some promise of success [1].

The major problem with poverty programs may not be the inequities in delivery of services of these programs to rural or urban people. Given full equity, poverty may persist even under conditions of greatly expanded funding levels for these programs. I agree with Moynihan [2] that the extraordinary commitment

[1] It is somewhat strange that Owens' references do not include either of these reports.

made by the national government to end poverty in America was accompanied by a collection of fragmented programs which did not add up to an effective policy. Many of the programs gaining status in this collection were initiated years previously in the 1960's, and under conditions and for purposes differing with the conditions and purposes of programs created in the past decade. The content of Owen's closing sections on summary and conclusions and policy implications did not strike me as especially innovative. He did a creditable job in updating some of the statistics on poverty. That, of course, is where we must start in the task of creating policy and effective programs for alleviating poverty.

References

[1] *Manpower Report of the President*, Washington, U. S. Government Printing Office, 1971, Ch. 4.

[2] MOYNIHAN, DANIEL, "Policy vs Program in the '70s," *The Public Interest*, 20:90–100, Summer 1970.

[3] The President's National Advisory Commission on Rural Poverty, *The People Left Behind* and *Rural Poverty in the United States*, Washington, U. S. Government Printing Office, 1967.

[4] *Report on Government Services to Rural America*, House Document No. 92-55, Washington, U. S. Government Printing Office, 1971.

Discussion: J. MARTIN REDFERN, *University of Arkansas*

Mancur Olson argued in 1963 that rapid economic growth is a profoundly destabilizing force, and both the gainers and the losers from economic growth can be destabilizing forces [6, pp. 532–533]. Moreover, contrary to what is usually assumed, economic growth can significantly increase the number of losers [6, p. 536]. And, Olson continues, the fact that some groups in the population may in the short run lose from rapid economic growth is made worse because societies in the early stages of industrialization rarely have suitable institutions for mitigating the adversities suffered by the losers in the process [6, p. 537]. I am going to assume that this is a reasonably accurate description of economic growth in and around the main rural poverty concentrations in the South: namely, the Ozarks, Appalachia, the Coastal Plains, the Black Belt of the Old South, and the Mexican-American concentrations along the southern border [5, p. 3]. The rural poor of the Ozarks and Appalachia are predominantly white.

Olson's framework allows me to discuss the two key points, as I see them, of Carl Gotsch's paper [2] which emphasizes, first, the importance of institutions in determining the effects of technology. To be more specific, the distribution of property and power is crucial [2]. By so doing, he follows in the footsteps of Castle and Youde who pointed out that 20 years ago S. V. Ciriacy-Wantrup called attention to the importance of treating institutions as variables rather than constraints [1, fn. 4].

Second, Gotsch notes that many policy recommendations regarding the adoption of technology consider only the first-round effects. Thus, "to fail to relate technology to the social and institutional context of its use has tended to produce policy advice that is . . . at worst the basis for development strategies that are likely to be socially disastrous in the long run" [2]. Thus, the second- and succeeding round effects need to be taken into consideration.

Measurement of these second-round effects and of the interaction of technology and political power is a very worthy one, although I suspect the meaningful measurement of either is currently beyond the scope of the science of economics or any multi-disciplinary combinations of economics and other disciplines.

The 1963 article by Olson [6] mentioned previously on economic growth provides one link between Gotsch and Emiel Owens. Owens points out that rapid rates of economic growth and technical change require a *continuous* reallocation of human resources which further accentuates the effects of human capital deficiencies on disadvantaged individuals and groups [7]. The phrase "continuous reallocation" is a key one. Owens documents deficiencies of the poor other than lack of education and points out that "the delivery service systems of the new antipoverty programs are fragmented and not well organized to assist the deprived and disadvantaged most in need of help" [7]; within a particular poverty group, the law of poverty programs is *not* "help the worst first."

Owens makes an additional important point that many rural poverty families never receive financial assistance in any form from any

government source. Also, using a money income definition of poverty, those who have moved out of poverty probably have not moved very far out.

The programs that Owens advocates for the 1970's and beyond, based on his analysis of the 1960's, are ones that most people are familiar with and that few would quarrel with. I did wonder, however, why the guaranteed minimum income concept is not discussed explicitly since Owens states that some system of transfer payments will be needed for many of today's poor.

One technical comment is in order with regard to the human capital deficit of non-whites. All other data I have seen show results comparable to the ones presented; however, I do not think the income elasticity of education of Texas non-white rural poor can be compared with the income elasticity figures for U. S. white males. The appropriate comparison, if the data were available, would be with a sample of Texas white rural poor.

Surely, though, Owens' most important point is that during the 1960's the view of poverty changed. It seems logical to me that the new view of poverty which developed in the 1960's will be sustained in broad terms and that the future evolution of poverty policy will be in terms of setting the "rules of the game" and modifying these rules through the political process.

Several additional points need to be made. First, there is usually a choice to be made between efficiency and equity by policy makers responsible for anti-poverty programs, by legislators, and by voters. Efficiency is maximum income per public dollar spent and equity is the favorable distribution of benefits. Most agricultural economists are taught the Hicks-Kaldor welfare criterion in graduate school—roughly, that a policy is desirable if the gainers from it can compensate the losers. But as Tweeten [9, p. 8] points out, "Compensation of losers was not stressed by theorists nor usually attempted in practice, and the focus turned almost wholly to efficiency." In practice, this means that action agency personnel have been oriented to make limited public funds go as far as possible to lift incomes of their clientele [9, p. 8].

Obviously, a great deal of education of legislators and voters will be necessary to demonstrate to them that modified programs which are orientated to achieve more equity and less efficiency are in their interest, and are not simply reallocating more of the taxpayers' dollars to "coddling the poor."

Several agricultural economists have already started thinking about this educational process. Patrick Madden is one of them. He points out that when the poverty threshold is measured by family income alone, other important dimensions related to overall well-being are ignored. An incomplete listing would include wealth, access to basic services, social mobility, education, apathy, and alienation [4, p. 311]. All of these apply to the rural poor in the Ozarks, and the short-run prospects for improvement in any of these dimensions are not good. Their lack of success in staying in the mainstream of society is reinforced by a value system which causes them to turn inwards to the family. Madden suggests that "Maslow's 'hierarchy of needs' provides a useful perspective for interpreting needs of rural people" [4, p. 311]. These needs are (1) physiological needs (hunger and thirst), (2) safety needs (a secure, stable, predictable existence), (3) belongingness and love needs (both giving and receiving), (4) esteem needs (self-respect and the esteem of others), and (5) the need for self-actualization (to realize one's full potential). Even if the rural family has satisfied the first three needs, they might still turn inward and away from the mainstream of society because to get into the mainstream of society they have to risk failure. To quote Ford [in 8, pp. 28–29], "The loss of self-esteem that inevitably attends failure . . . represents a good deal to those who have little else but pride."

A colleague at Arkansas, Bernal Green, has also used Maslow's "hierarchy of needs" as an integral part of an attempt to find a better definition of economic development [3].

In similar vein, Tweeten [9, p. 18] has recently pointed out that agricultural economists have made the judgments that rural development is desirable and that public funds are justified for use in promoting rural development; yet the profession currently has little objective evidence to back up either of these judgments.

The papers by Owens and Gotsch, and the additional research cited above, suggest that there is much useful research to be done in defining, analyzing, and planning rural development, economic growth, and a solution to rural poverty.

References

[1] CASTLE, EMERY N., "Institutional Reform: Implications for Agricultural Economics," presented at the American Agricultural Economics Association annual meeting, Carbondale, Ill., Aug. 1971; *Am. J. Agr. Econ.* 53:778–784, Dec. 1971.

[2] GOTSCH, CARL H., "Technical Change and the Distribution of Income in Rural Areas," presented at the winter meeting of the American Agricultural Economics Association with the Allied Social Sciences Associations, New Orleans, Dec. 1971; *Am. J. Agr. Econ.*, this issue.

[3] GREEN, BERNAL L., "Development Defined: New and Old Psychological Concepts Point to a Re-examination of Goals," unpublished manuscript, submitted to *Science*, Dec. 1971, mimeo.

[4] MADDEN, PATRICK J., "Social Change and Public Policy in Rural America: Data and Research Needed for the 1970's," *Am. J. Agr. Econ.* 52:308–314, May 1970.

[5] National Advisory Commission on Rural Poverty, *The People Left Behind*, U. S. Government Printing Office, Washington, Sept. 1967.

[6] OLSON, MANCUR, "Rapid Growth as a Destabilizing Force," *J. Econ. Hist.* 23:529–552, Dec. 1963.

[7] OWENS, EMIEL W., "Poverty Programs in the 1960's: A Survey," presented at the winter meeting of the American Agricultural Economics Association and the Allied Social Sciences Associations, New Orleans, Dec. 1971; *Am. J. Agr. Econ.*, this issue.

[8] TWEETEN, LUTHER G., *Rural Poverty: Incidences, Causes, and Cures*, Okla. Agr. Exp. Sta. Proc. Series P-590, July 1968.

[9] ———, "Applying Welfare Economic Theory to Rural Development Research," presented before the Southern Farm Management Research Committee, Atlanta, Nov. 18, 1971, mimeo.

Communications

FUTURE CENSUS DATA FOR AGRICULTURE*: COMMENT

The assertion that our statistical definitions of farms and farm population are in need of adjustment to bring them into alignment with the realities which they purport to measure is hardly new. The present writer was a junior author of a paper [1] published in 1944 where it was argued that the gross statistics which were available did not adequately meet current needs. That paper proposed a "few simple, distinct and clearly recognizable classes, and a tabulation for each of these classes of such data as are needed for recognizing and understanding the problems related to them" [1]. The Economic Class of Farm is the present-day response to that suggestion. There is little dissent from the view that such a scheme of classification has significantly increased the utility of the statistics and has provided a basis for many useful analyses. Nevertheless, there continues to be widespread use of the gross number of farms. It is frequently used as a divisor to arrive at averages per farm, even though knowledgeable analysts know full well that American agriculture in 1971 is far too diverse to be categorized in that manner.

Consideration should now be given to excluding from the statistics the relatively large number of units which make little contribution to total agricultural production.

Planning for the 1974 Census of Agriculture should be started early. If there are to be fundamental revisions in the basic approach to that census, then there is an added urgency to this matter. Concepts are not readily changed—they become woven into statistical series, into action programs, and even into legislation. The implications need to be carefully reviewed and the consequences of any action thoroughly evaluated. This simply underscores the urgency of getting on with this task.

From the standpoint of the Bureau of the Census and of any other agency which might wish to collect information concerning farms, there is also the operational question of how to identify the potential respondents to any inquiry in the field. Procedures now in use have developed over a long period of time, based on a situation in which it was relatively simple to identify a place or an enterprise as a farm. Before 1969 the procedure in the Census of Agriculture required that every household in the open country be queried to establish whether it met the criteria for inclusion as a farm. Absentee operators of open land were to be interviewed where they lived. As long as it was feasible to conduct the Census of Agriculture simultaneously with the Census of Population, only minor operational problems were created. However, it became clear that in terms of field operations it would be better to carry on these two censuses at different times. In the 1964 census, of the approximately 7.7 million households queried, about 3.4 million met the criteria for inclusion in the Census of Agriculture. About one-sixteenth (some 0.2 million) of the questionnaires were eliminated during office processing because they did not meet the minimum criteria for inclusion. Even with this procedure, some units (especially the smaller ones) were missed. It was estimated that about 24 percent of the farms of less than 10 acres were not included in the census, although the underenumeration of the larger farms was substantially less.

Because of the very small contribution which the smallest units make to total production, a relatively high rate of missed units has little effect on most of the statistics. However, the total number of farms *is* affected by the differentials in the completeness of the enumeration. In the USDA's annual estimates, census figures on the number of farms for 1964 were increased by nearly 9 percent.

By 1969 it had become apparent that the search for farm units through a general household listing in rural areas was no longer effective. The fact that units of any significant size are likely to be listed in administrative records suggested that such records might be used effectively to identify those units which should be included in the universe. Income tax returns appeared to be a likely source. Certain farm operations are identifiable in the records of the Social Security Administration and in those of the USDA agricultural programs. Tests indicated that the available lists would provide a means of identifying almost all of the significant agricultural operations. But it appeared that as many or more of the very small units which were difficult to identify by the older procedure would also be missed under the new one.

For much of American history there has been a close relationship between the place of residence and the place of work of persons primarily engaged in agriculture. However, agriculture has not been immune to the general practice of separating the work place from the place of residence, a fact which has made it desirable to find an alternative to door-to-door screening, which can be applied effectively only in rural areas.

* The views expressed here are my own. Although they have been discussed with the Bureau of Census, the USDA, and others, none of these organizations has endorsed them.

Operational difficulties in identifying the units to be included in the universe are not the primary reasons for a review of the present definitions. However, elimination of marginal units from the universe of farms would lead to an increased likelihood that virtually all units in the newly defined universe could be included in any data-gathering activity.

It has been argued that gross value of sales is an inadequate basis for classifying farms and, presumably, also for identifying the units to be included in any category. Inputs might be viewed as a more satisfactory basis, and from the point of view of some analysts, this is undoubtedly the case. However, within the framework of what is feasible in a census, or in general purpose surveys, there are very real difficulties in collecting the data required to classify farms on this basis.

It would be desirable to plan the 1974 Census of Agriculture with the basic assumption that it is to be limited to units which contribute in a significant way to commercial agricultural production, omitting what are essentially subsistence or part retirement farms under present definitions. This will require a new set of criteria for the definition of a farm. It is doubtful that a unit with a gross value of sales of less than $5,000 should be considered as a farm for statistical purposes. Unusual circumstances which may hold sales in a single year below their normal value should also be taken into account. Had such a definition been in effect in 1964 the number of farms reported in that census would have been about 1.4 million rather than 3.2 million. However, 92 percent of the total value of sales would have been included. It is likely the 1969 census will show that these farms contributed an even larger share of total production. Even for some major crops traditionally grown on relatively small operations, there is increased concentration of production on the larger units. This is one of the matters needing careful study.

If such a revision is to be made, a sample survey procedure should be developed to measure the impact of the new definition on a national and possibly regional basis. It would not be necessary to provide such statistical bridges for counties.

Agriculture has become so closely interwoven with other sectors of the economy that some of the information needed for analytical studies relating to agriculture must be sought in other sources of data. A beginning was made in the 1969 Census of Agriculture through a special survey of agricultural services, although this is recognized as a preliminary effort still requiring considerable expansion. Since more of the activities once closely associated with agriculture are being carried on at nonfarm locations, there is a clear need for closer integration with other censuses dealing with economic activity. We also need to recognize the rapid changes taking place in the managerial and financial roles involved in agriculture, including contract arrangements, advisory management relationships, and corporate and other forms of ownership and financing. Vertical integration and increasing participation of conglomerates in agricultural production should be subjected to special attention and study. Some clear formulation of the concept of the entrepreneur as it applies to modern-day agriculture is needed. Traditional concepts of tenure arrangements are no longer adequate, but as yet no satisfactory substitutes have been developed.

The statistics provided by the Census of Agriculture and, to a large extent, those provided by USDA are oriented to specific geographic areas—states, counties, and, to some extent, townships and similar smaller areas within counties. It has become increasingly difficult to assign each enterprise to a specific small geographic area; accordingly, the census no longer tabulates farms and farm production in terms of townships. A headquarters can be assigned to a specific location, but if it is responsible for activities over a considerable area, the attribution of the activities and production to the headquarters area loses its meaning. We should study application of the concept of the establishment, analogous to that used in the censuses of Manufactures and Business, although the fact that most forms of agriculture require extensive land areas may introduce some difficulties.

It is assumed that the census should continue to relate the operations of scattered plots to the economic units of which they are a part. Statistics for very small areas would require separate enumeration of individual tracts of land which would provide data on acreages, land use, and crop production. Such an approach, however, would lose the emphasis on the enterprise and on the structure of agriculture which has characterized the American approach to gathering a large body of agricultural statistics.

Subsistence agriculture is relatively unimportant today, although it long played an important role in our history and as recently as the 1930's. The growing specialization of commercial agriculture has brought farm families increasingly into the market place for agricultural products destined for human consumption. Disappearance of the barnyard flock and "egg money" to buy groceries illustrates the trend. The number of families producing a significant portion of their food has declined, as has the number of operators using agriculture as a means of continuing productive activities on a reduced scale as they reach old age. There is also an apparent reduction in the number of persons who carry on a limited amount of agriculture but seek their major source of support elsewhere. Such units can safely be disregarded in any future Census of Agriculture. The problems associated with these and other agricultural operations which do not provide sufficient support to raise their practitioners above the poverty level are clearly not delineated in a Census of Agriculture. The Census of Population, with its effort at complete coverage of persons and families, can provide more complete and useful information for the analysis of problems in relation to income, welfare, occupations, and retirement.

News reports tell of communal establishments en-

gaged in agricultural production primarily for consumption by their members. Presumably, it is the intent of such groups to remain outside the market for agricultural products. Unless such a development becomes much more widespread, it presents no important problem for the Census of Agriculture. If such groups find it sufficiently profitable to engage in agricultural production and sell some of their produce, they would then come into the system in the same way as any other agricultural enterprise.

Farm Population

A related concept which needs careful review and possible elimination from the statistical series is that of the farm population. When it was developed in the 1920's, there was still a large measure of identification of the people living on farms with the conduct of the agricultural operation. However, this identity has been seriously eroded. Today it is neither a clear residential nor industrial concept. A recent report issued jointly by the USDA and the Bureau of the Census shows that the farm population has dropped below 10 million, a loss of about one-third during the 1960's. A total of 4.3 million of these farm residents were in the labor force, but only 54 percent were employed solely or primarily in agriculture—as compared with 64 percent at the beginning of the decade. Conversely, there has been a continuous decline in the proportion of persons working in agriculture who live on farms. As recently as 1960, three-fourths of the persons working in agriculture lived on farms; by 1970 this proportion had dropped to 63 percent. The hired man who was once a part of the farm household has now become a commuter from his nonfarm residence, and there is an increasing proportion of farm operators who no longer find it necessary or desirable to live on the farm which they are cultivating.

Hathaway, Beegle, and Bryant, in their report on the *People of Rural America* [2], propose an alternative approach to a residential classification of the population. Their basic distinction would be between metropolitan and non-metropolitan areas, utilizing for this purpose the standard metropolitan statistical areas defined by the Office of Management and Budget. Within each of these two major divisions they would distinguish between urban and rural residence and then divide the rural into village and open country. They recognize the difficulty in distinguishing open country and village, but suggest that a lower cutoff (such as a population of at least 200) might be used to define villages whether incorporated or unincorporated.

They recognize that there would be difficulties in dealing with diverse settlement patterns and modes of residence such as string towns, resort areas, isolated mining and industrial developments, etc. The concept of the urbanized areas (densely built-up areas adjoining cities of 50,000 or more) would be extended to cities of 25,000 or more, thus removing some essentially urban settlements from the open country classification.

Concern with the agricultural population is a long-established tradition, although there is no full agreement on how this concept is to be defined in the present-day U.S. Hathaway and his colleagues [2] call for greater coordination between the censuses of Population, Housing, and Agriculture and the development of information concerning the persons dependent on agriculture for a living. They call for the preparation of demographic data for populations associated with agriculture and for the inclusion of everyone who has income from an agricultural source. Such proposals will be subject to further evaluation when the full returns from the 1970 Census of Population and Housing are available.

Although the concept of the rural farm population has served social scientists and administrators for at least half a century, it is doubtful it can usefully be continued. In view of the new situation and the emerging needs, we must develop a new set of concepts.

Summary

It is time to re-evaluate the concepts underlying statistics collected in the Census of Agriculture and in similar data-collecting and publishing activities. The present concept includes a large number of units which make little contribution to total agricultural production and have little relevance to agricultural programs. To the extent that the individuals and families involved with these small units present problems affecting public welfare, these are not problems within the framework of agriculture. Therefore, the data needed for planning programs should be derived from other sources, primarily the Census of Population. If, as has been projected, 90 percent of the agricultural production in 1980 will come from between 500,000 and 600,000 units, there would seem to be little purpose in maintaining a concept which might lead to a finding that there are 2 million farms at that time. Statistics of industrial production omit products of establishments which have no employees and those of retail trade omit enterprises with annual sales of less than $2,500. The activities of these small enterprises cannot affect trends in overall totals. The functions they perform are less economic than human and social. In this respect modern American agriculture is not much different.

As agriculture becomes increasingly commercialized, the traditional relationship between agricultural operations and farm residence loses much of its former meaning. To the extent that it is needed, information concerning persons directly or indirectly related to agriculture should be collected through the Census of Population and sample surveys. The farm residence concept could usefully be replaced with a concept of residence that distinguishes compact settlements from those which are dispersed.

CONRAD TAEUBER
Bureau of the Census, U.S. Department of Commerce

References

[1] BENEDICT, M. R., H. R. TOLLEY, F. F. ELLIOTT, AND CONRAD TAEUBER, "Need for a New Classification of Farms," *J. Farm Econ.* 26:694–708, Nov. 1944.

[2] HATHAWAY, DALE E., J. ALLAN BEEGLE, AND W. KEITH BRYANT, *People of Rural America*, Washington, U. S. Government Printing Office, 1968.

FUTURE CENSUS DATA FOR AGRICULTURE: REPLY

Economists have failed in their responsibility to provide a relevant theoretical framework for data collection by public statistical services. By his proposal to reduce census coverage of farms and improve the efficiency of data gathering, Taeuber is simply filling a void left by the economists who have not told him what data to provide.

Those who utilize agricultural statistics agree that the farm must be redefined and the criteria for economic classification revised. Nowhere is change more critical than in the conceptual framework where comprehending interrelationships in the various sectors of agricultural economy is a necessity.

However, this concensus deteriorates rapidly when specific questions are asked: How should a farm be defined? Should we even be thinking in terms of "farms"? Why not establish a conceptual framework in terms of activities and impute values to each?

Why have we been unable to reach an adequate solution to this problem of collecting agricultural statistical data? Is it a lack of concern, or are there more pressing problems?

Many economists, involved in refining their models, equations, and formulas which require more precise data, do not stipulate what data the statistician should gather. Some economists even seem to get a strange thrill from manipulating data. What they need to recognize is the value of *multi-purpose* data collected on a *regular* basis, as contrasted with "*one-shot*" surveys that fit only one model.

The present farm definition is all inclusive. Taeuber's proposal of a cutoff at $5,000 gross sales would have a major impact on the USDA's statistical series and program operations. Thorough and objective evaluation of the consequences of this proposal is a must. A major obstacle, however, lies in previous legislation which tends to preserve a statistical profile out of touch with today's conditions. Federal grants to states for research, extension, and other farm-related activities have caused rural leaders to oppose any apparent reduction in the number of farms, farmers, farm population, farm labor, etc.

Data needs should not be determined by public statistical services on the basis of political or social pressure from vested interests. A review of Taeuber's paper suggests that agricultural census data have been dictated more by social considerations and desires of agribusinessmen than by economic rationale. Is this desirable? Can it be corrected? And by whom?

The Statistical Reporting Service (SRS) has for many years depended upon the Census of Agriculture in making current estimates of crop production and livestock numbers. Regression techniques are used in plotting current indications from crop reporter panels against census benchmarks to remove persistent biases. In the past decade, however, the SRS has shifted to probability sampling for its major surveys of crop acreages and yields and livestock numbers. Samples are designed to produce both national and state estimates with relative standard errors of about 2 percent at the national level and about 6 percent at the state level for major crop acreages and livestock inventories. This shift to probability sampling means the benchmark use of census data by the SRS is no longer essential for estimating major crop and livestock items, especially at the national level. Multiframe sampling, combining use of list frames and area segment frames in designing samples for a number of special surveys, is reducing sampling errors for both major and minor crops as well as for state estimates.

The Census of Agriculture continues to be the basic source for county and other small area data. Whatever decision is reached on farm definition as well as other census concepts, the continuing need for small area data must be recognized.

USDA has been devoting more attention to questions of agricultural structure. Recent studies include one contracted with Dick Foote entitled "Concepts Involved in Defining and Identifying Farms" and Eldon Weeks' report of "Aggregate National Agricultural Data—Status and Alternatives." Further, a USDA study committee has been formed by Don Paarlberg to review the question of farm definition. Several alternatives and the implications of each are under study.

A broader distribution of agricultural economic data sources, including the entire family of economic censuses, is a necessity for the future. Perhaps 1974 would be a good year to test census procedure covering all establishments engaged in agriculture-related business activities. Early development of the conceptual framework for such coverage would be a big step forward.

HARRY C. TRELOGAN
Statistical Reporting Service,
USDA

EXTERNAL CREDIT POLICY FOR LATIN AMERICA: COMMENT

In an age of specialization, model construction, and highly specific theoretical or problem-solving approaches, far too little time is spent on synthesizing the disparate although interconnected parts. Thus, Adams' cogent but sometimes speculative discussion [1] of agricultural credit in less developed countries must be applauded. While his article is a signal contribution, it should be pointed out that some of the material is subject to alternative interpretations which can lead to conclusions quite different from some of his. The purpose of this comment is to point out some of the alternatives, thereby amplifying the utility of the analysis of agricultural credit and its role in development, as well as raising some issues that need clarification.

First, Adams compares a series of ratios of agricultural credit to production of 18 Latin American countries with the United States and Taiwan and concludes that, "At best, these . . . present a mixed case for agricultural credit shortage . . ." [1, p. 165]. This conclusion is reached despite very low ratios in several countries where the existence of a large subsistence sector is used to explain such ratios. It could be argued, alternatively, that these imply a shortage of available credit for the subsistence sector and that concessional rates and supervision are justified, indeed required, to move those farmers into the market economy, while avoiding their eventual displacement to the mushrooming urban slums [4]. But even if use of the overall credit-to-production ratio is adequate, this does not mean that there is no credit shortage. Perhaps production is limited because additional credit is not available to many producers. If they "could" obtain credit, output would expand although the ratio might remain unchanged. A goal in many less developed countries is to expand agricultural output, and a credit bottleneck may limit its achievement if additional inputs obtained only by use of borrowed funds are required, a situation apt to exist for the majority of smaller operations. With total agricultural credit in 18 Latin American countries equal to that outstanding in three U.S. lake states, it seems unlikely that credit availability is adequate!

Another measure used to suggest "that Latin America may not be too badly off" [1, p. 165] is the ratio of agricultural credit to total credit—about 33 percent but ranging from 6 to 73 percent. Again, this implies (1) that total credit is adequate, at least if this ratio supports the hypothesis that there is no agricultural credit shortage, and (2) that although agricultural employment is still only a little less than half of total employment (although agricultural output to total output is more closely related to the credit ratio), one-third of the credit extended is adequate.

Finally, Adams uses a lack of relationship between increases in credit and agricultural production to indicate that there may not be a credit shortage. At least one study by Obermiller [3] has shown a strong relationship of bank credit per hectare and output per hectare for the 1957–1966 period. Obermiller used a combination of cross-sectional and time-series data from the Latin American countries to make a functional analysis.

A second major point raised by Adams concerns concessional interest rates for farmers. He argues against continuing these largely on an allocational basis. Perhaps this issue should be subdivided into two subsets: credit made generally available and that destined specifically for the smaller commercial and subsistence farmers. A point made was that supervised credit programs, because of the high cost of supervision, did not meet out-of-pocket expenses, and that this coupled with inflation results in reduced effective lending ability unless there are continued infusions of fresh funds. As suggested, appropriate fiscal and monetary policies might be used to control inflation and lessen that effect. The cost of supervision could be removed only by eliminating such programs. Adams seems to argue for this on the basis of the possibility of "flabby administration" where profit is apparently not a motivation for the credit agency.

He also suggested, however, that such programs have been beneficial for smaller producers in Colombia [1, p. 168], a conclusion confirmed by Colyer and Jimenez [2]. Successful modernization by many smaller producers may require supervision and educational programs to guide development, due in part to a generally low level of effective literacy. The question is whether these should be tied directly to credit or performed separately by an extension service. Separate programs seem to be less desirable, at least in those areas where a substantial proportion of small, relatively low-skill producers exist. Since use of extension is apt to be voluntary, the needed interfacing may not result where the programs are separated. Thus, supervised credit programs offer an excellent method of directing the flow of capital to an important sector numerically, and one that would be left out in the ordinary functioning of the credit market. Although the increase in output *might* not be as great as when the same amount of total credit is extended to those who can obtain the funds through the normal channels, the long-run effects may be more beneficial than if the smaller farmers were neglected. While various means of subsidization of the modernizing process may be feasible, it seems likely that some procedure like supervised credit may be necessary because of the previous lack of investment in rural education.

The argument of high administrative costs and consequent "flabby administration" can be avoided if it is recognized that the supervisory costs are, to a large extent, educational costs. By maintaining a separate appropriation-levied budget for those costs, the interest earnings would be left to pay for the more ordinary costs of administration. This would

allow judgment of the managerial effectivity in handling the funds as well as in preventing erosion of the portfolio by high costs. Modification of procedures should handle the criticisms leveled against the supervised credit programs while allowing their continued benefits for smaller, resource-poor (human and physical) producers.

Thus, while agreeing with the general tenor of Adams' evaluation, I do not feel that allowing market forces "more sway in the allocation of these funds" [1, p. 169] is completely realistic when the structure of the rural population is considered. As more farmers become capable, financially and through experience, they can be moved into the market to obtain their funds. But it is overly optimistic to expect most producers, in a numerical sense, to be able to compete equally with those possessing greater resources and training. Allowing market forces to allocate loanable funds will only worsen an already undesirable pattern of income distribution and will force smaller producers out of agriculture and into an already gutted labor market.

DALE COLYER
West Virginia University

References

[1] ADAMS, DALE W, "Agricultural Credit in Latin America: A Critical Review of External Funding Policy," *Am. J. Agr. Econ.* 52:163–172, May 1971.

[2] COLYER, DALE, AND GUILLERMO JIMENEZ, "Supervised Credit as a Tool in Agricultural Development," *Am. J. Agr. Econ.* 52:639–642, Nov. 1971.

[3] OBERMILLER, FREDERICK W., "Factors Associated with Agricultural Development and Growth in Latin America," unpublished Ph.D. thesis, University of Missouri, 1969.

[4] THIESENHUSEN, WILLIAM C., "Population Growth and Agricultural Employment in Latin America, with Some U.S. Comparisons," *Am. J. Agr. Econ.* 51:735–752, Nov. 1969.

EXTERNAL CREDIT POLICY FOR LATIN AMERICA: REPLY

Professor Colyer asserts two major points in his comment. The first is that agricultural credit shortages, especially among subsistence farmers, are a major problem in Latin America. The second is that concessional interest rates on credit to small farmers are required and justified. I partially agree with his first point but feel very uncomfortable with his second.

In the article [1] critiqued by Colyer I suggested that agricultural credit shortages may be less pressing in Latin America than many people have felt. My main concern was to encourage policy makers to stand back and take stock after the major increase in agricultural credit realized during the 1960's. I fully agree that under current low interest rates policies it is very difficult to discern the level of credit demand which would result if interest rate reflected opportunity costs for capital. Results from recent research in Brazil [6] suggest, nevertheless, that at least in some areas too much credit is being loaned to a few farmers, and that if credit were priced at its opportunity cost some rural areas may have a surfeit of loanable funds.

While I feel that too much emphasis is being placed on *overall* agricultural credit shortages, I share Colyer's concern with the general lack of small farmer participation in bank credit in Latin America. I concur with the research conclusions of Colyer and Jimenez [3] in their Colombia study; a number of small farmers can make profitable use of bank credit. Rao's research [5] on the high marginal returns to credit use among small farmers in southern Brazil lends further weight to this conclusion. I also agree that at least some of the supervision costs associated with small farmer credit programs ought to be borne by society as part of its educational responsibilities. My main concern is with the rate of interest levied on credit aside from the supervision costs.

Colyer argues in favor of low interest rates largely on the grounds that they are required to elicit loan requests from small farmers. He, like many others, implies that irregularities in small farmers' demands are gumming up the credit delivery system. In contrast to Colyer's view, I would argue that the low interest rate policy itself is an important factor in explaining why small farmers are not participating in bank credit [2]. I would focus more on the supply side and ask the question, why don't banks provide credit to small farmers?

Advocates of inexpensive credit regularly ignore the fact that interest rate policies are a two-edged instrument. Low rates not only encourage credit usage, but they also seriously affect banks' financial interests to make loans which carry concessional terms. With low administered rates on agricultural credit it should be no surprise that, unless forced to do so, private banks in Latin America lend very little to agriculture [4]. It also should not be a surprise that government banks which do lend to agriculture tend to minimize their costs and lending risks by concentrating on large, well-secured loans. At the close-to-zero or negative real rates of interest charged on agricultural credit, banks face a virtual horizontal demand schedule from people who have excellent credit ratings. Government administrative directives aimed at spreading loans to a broader audience than banks' own financial interests would dictate are only partially successful. I feel the low interest rate poli-

cies destroy the incentives of banks to loan to small borrowers, encourage individuals who are wired into the banking system to overuse credit, and force governments to set up costly, redundant agencies and programs to channel credit to small farmers.

Cheap credit policies also have other unfavorable impacts. The factor-pricing distortions which a low interest rate policy introduces and their impact on employment have been poorly understood. In the poverty-stricken sugar zone of northeast Brazil, for example, rather abundant agricultural credit has been available mainly for large borrowers at nominal interest rates which ranged from zero to 18 percent per year during the late 1960's and 1970's. These rates along with inflation of 20 percent or more per year have resulted in negative real interest rates being charged. At the same time, wage legislation over the past couple of decades has significantly increased the real cost of rural labor to sugar producers and ranchers. With these policies it should be no surprise to find large producers emphasizing capital investments which substitute for labor or developing enterprises which require less labor input.

Low interest rates on credit also seriously limit the financial incentives which can be offered for institutional savings in the rural area. Administratively it is difficult to pay higher rates on deposits than are collected on loans. A self-fulfilling prophecy is thus maintained. It is assumed that little or no savings capacity exists in the rural area. Policies then are constructed which make sure this assumption is fulfilled. Low interest rates on savings effectively block the institutional mobilization of funds which might be surplus of internal consumption and investment needs at realistic interest rates. With cheap credit available, farmers are encouraged to consume resources or transfer borrowed and owned funds out of agriculture.

I can see very few benefits and a number of serious disadvantages in the current policy of maintaining low interest rates on agricultural credit. Inexpensive credit is neither required nor justified for the small farmer. The rural poor would be better off with higher rates of interest. I feel that where profitable farm investments are available, most farmers will wisely use realistically priced credit. A farmer's decision to invest in his farm will not be seriously affected by real interest rates on credit which are a minus 10 percent, zero, or a plus 10 percent if investment returns are substantially higher. Policy makers and not farmers have "interest illusion."

DALE W ADAMS
The Ohio State University

References

[1] ADAMS, DALE W, "Agricultural Credit in Latin America: A Critical Review of External Funding Policy," *Am. J. Agr. Econ.* 52:163–172, May 1971.

[2] ———, L. HARLAN DAVIS, AND LEE BETTIS, "Is Inexpensive Credit A Bargain for Small Farmers? The Recent Brazil Case," Economics and Sociology Occasional Paper No. 58, Dept. Agr. Econ. and Rural Soc., The Ohio State Univ., Jan. 1972.

[3] COLYER, DALE, AND GUILLERMO JIMENEZ, "Supervised Credit as a Tool in Agricultural Development," *Am. J. Agr. Econ.* 52:639–642, Nov. 1971.

[4] ERVEN, BERNARD, AND NORMAN RASK, "Credit Infusion as a Small Farmer Development Strategy—The Ibiruba Pilot Project in Southern Brazil," Economics and Sociology Occasional Paper No. 48, Dept. Agr. Econ. & Rural Soc., The Ohio State Univ., Dec. 1971.

[5] RAO, BODEPUDI PRASADA, "The Economics of Agricultural Credit-Use in Southern Brazil," unpublished Ph.D. thesis, The Ohio State University, 1970.

[6] TOMMY, JOSEPH LISSA, "Credit Use and Capital Formation on Small to Medium Sized Farms in Southern Brazil 1965–1969," unpublished Master's thesis, The Ohio State University, 1971.

THE GREEN REVOLUTION: A REPLY TO PROFESSORS RUTTAN AND MELLOR*

In this reply we examine a major methodological issue implied by the criticisms of Ruttan and Mellor [7, 13] to our recent paper [2] and reassess supply and demand responses to price changes.

Methodology

Mellor [7] suggests that our assumptions are arbitrary and that policy practitioners are guided by intuitive insights which are likely to produce more accurate results than those produced with quantitative tools and data. He does not indicate which specific assumptions he is questioning or in what magnitudes such questionable assumptions might alter elasticity estimates and/or forecasts.

In retrospect our assumptions appear quite reasonable. We might be faulted for assuming that "there will be no major war in the Far East or Southern Asia prior to 1976" [2, p. 287]. We did not want to speculate about the possibility of civil war between East and West Pakistan. And the assumption of "no war" in economic models is probably as sacrosanct as assumptions ever become.

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Among the positive results of our research is the provision of data series of area seeded, fertilizer demand, yields, prices, and trade for the major nation-producers of rice and for the world. Our methodology is unique inasmuch as the forecasting equations are not necessarily identical with equations used for estimating elasticities. Also, simultaneous estimates of rice price elasticities are made for the first time as far as we know. Non-equation estimates of output in miracle-grain-using nations take into account many of the factors that do not lend themselves to statistical formulation. The subsequent "marriage" of statistical and nonstatistical techniques also is, as far as we know, unique. Just why this methodology was considered to be so "ad hockery" as to offend Ruttan's "esthetic sensibilities" [13] is not clear. Indeed, we see several advantages of our methodology: (a) The parts of a systematic economic model are always available for reexamination. When "policy practitioners" are wrong, it would be useful to know why. Explicit statements of assumptions and procedures are useful as means of determining sources of error. (b) Contrary to Mellor's implication, policy practitioners frequently do use data and do quantify. Moreover, interactions of multiple variables defy purely mental conceptualization.

Area Response to Price Changes

In terms of specifics, Ruttan's "skepticism is greatest with respect to the production relations." In our results, commodity prices affected the amount of capital (fertilizer input) utilized for production but not the area of land. In support of our conclusions, we can only offer the statistical estimates and the corresponding tests of reliability. Details of these results were not provided in the original publication or here because of lack of space.

The authors of the supply literature listed by Ruttan [1, 4, 5, 6, 12] used acceptable econometric techniques, and their results were surprisingly consistent with ours. Only comparable elasticity estimates for the Punjab region and two regions in the Philippines (Southern Tagalog, Eastern Visayas) had significant and relatively large long-run price elasticities with respect to rice acreage. But the Punjab results are for a period, 1914–45, in which population pressures on land were not as substantial as they have been since. Therefore, Punjab results may not be applicable to a period of intense population pressures on land and none of the regional results are applicable to an entire nation. In the aggregative Philippine estimates for 1947–63, which are coauthored by Ruttan, the estimated long-run aggregate price coefficients are actually negative. Nonetheless, Ruttan's elasticity optimism may well be justified for *certain regions*.

Price Elasticities of Demand and the Zero Sum

Mellor [7] suggests that "estimation of the effects of a major new technology on trade patterns requires estimates of . . . the effect of the new technologies on income distribution and hence on the structure of demand." Our paper addresses itself to the effects of the new technology on rice trade patterns; our failure to extend the study to the patterns of trade in all other commodities and services is more a reflection of impending fatigue than a weakness in our analysis. We did indicate that new technology has a direct bearing upon income distribution. In fact, we argued that the main problems between today and 1975 probably relate to income distribution and levels. But we doubt that such income distribution changes will alter the structure of demand in such a way that the price elasticities of demand for *rice* will be greatly affected by 1975.

Our neglect of the structure of demand, according to Mellor, "probably causes substantial underestimation of the demand elasticities" [7]; he does not specify *which* demand elasticities (own-price, cross, income). We presume that the reference is to the own-price elasticities of rice demand which we estimate as zero for most nations. These elasticity estimates differ markedly from those postulated by Mellor [8, 9, 10] elsewhere. After a thorough review of these references and others [11, 15, 16, 3], we found the Slutsky-Schultz price elasticities that Mellor apparently leaned upon in his criticism of our results to be very deficient.[1] This is not to argue that we believe our research to be without flaws. Throughout the paper we identified certain problem areas and indicated which elasticities we rejected [2, p. 292].

Forecasts

Finally, we can compare our forecasts with those developed by the USDA [14]. Our total world consumption estimate is 0.82 percent below the USDA estimate for 1975. Our world production estimate is 3.3 percent above the USDA's. This latter difference is probably explained by our development of the higher-yielding-variety production tables by hand. For country estimates, only Japan's appear to differ significantly with both our production and consumption estimates under the assumption of a "free mar-

[1] Mellor's main reliance is upon the Slutsky-Schultz condition [15, p. 111] that the cross-price plus the own-price plus the income elasticities sum to zero. But the own-price elasticity will equal or exceed income elasticity (as Mellor presumes) only if the sum of the cross-price-elasticities for substitutes equals or exceeds the sum of the price cross-elasticities for complements. Evidence on food income shares and the composition of diets in the rice-consuming LDC in [11, p. 326] suggests the reverse.

In [9, p. 963] Mellor estimates by a different technique a price elasticity for foodgrains in India of −.55 which he compares favorably with the Slutsky-Schultz result. But Mellor's estimation process is incorrect. First, even if otherwise correct, his is an estimate of the price elasticity of *excess demand*. Second, he fails to estimate the complete distributed lag relationship. Third, if higher order differences were included, the correctly estimated price elasticity of *excess* demand would be *much less than* /.55/.

ket" being about 13 percent higher. But the price behavior the USDA has *assumed* is relatively consistent with price behavior that our model generates. We believe that our study and recent USDA studies are complementary. We hope that someone soon will build a better model. And when it comes, we do not believe it will be off the top of some economist's head or off the bottom of some policy practitioner's pants.

E. RAY CANTERBERY
Florida State University
HANS BICKEL
University of Maryland

References

[1] BEHRMAN, J. R., *Supply Response in Underdeveloped Agriculture*, Amsterdam, North-Holland Publishing Company, 1968.
[2] CANTERBERY, E. RAY, AND HANS BICKEL, "The Green Revolution and the World Rice Market, 1967–1975," *Am. J. Agr. Econ.* 53:285–294, May 1971.
[3] FRISCH, RAGNAR, "A Complete Scheme for Computing All Direct and Cross Demand Elasticities in a Model with Many Sectors," *Econometrica* 27:177–196, April 1959.
[4] HUSSAIN, SYED MUSHTAQ, "A Note on Farmer Response to Price in East Pakistan," *Pakistan Develop. Rev.* 4:93–106, Spring 1964.
[5] KRISHNA, RAJ, "Farm Supply Response in India-Pakistan: A Case Study of the Punjab Region," *Econ. J.* 73:477–487, Sept. 1963.
[6] MANGAHAS, MAHAR, AIDA E. RECTO, AND V. W. RUTTAN, "Price and Market Relationships for Rice and Corn in the Philippines," *J. Farm Econ.* 48:685–703, Aug. 1966.
[7] MELLOR, JOHN W., "Discussion," *Am. J. Agr. Econ.* 53:296, May 1971.
[8] ———, *The Economics of Agricultural Development*, Ithaca, Cornell University Press, 1966.
[9] ———, AND ASHOK K. DAR, "Determinants and Development Implications of Foodgrains Prices in India, 1949–1964," *Am. J. Agr. Econ.* 50:962–974, Nov. 1968.
[10] MELLOR, JOHN W., AND UMA J. LELE, "Alternative Estimates of the Trend in Indian Foodgrains Production During the First Two Plans," *Econ. Develop. & Cult. Change* 13:217–232, Jan. 1965.
[11] MELLOR, JOHN W., THOMAS F. WEAVER, UMA J. LELE, AND SHELDON R. SIMON, *Developing Rural India. Plan and Practice*, Ithaca, Cornell University Press, 1968.
[12] MUBYARTO, "The Elasticity of the Marketable Surplus of Rice in Indonesia: A Study in Java-Madura," unpublished Ph.D. thesis, Iowa State University, 1965.
[13] RUTTAN, VERNON W., "Discussion," *Am. J. Agr. Econ.* 53:294, May 1971.
[14] WEST, Q. M., "World Grain Production Prospects and Trade Stabilization Measures in Southern Asia," in *Agricultural Revolution in Southeast Asia*, Vol. 1, eds., V. W. Ruttan *et al.*, Report of a SEADAG Rural Development Seminar Meeting, Honolulu, June 19–21, 1969; New York, Herbert-Spencer, Inc., 1970.
[15] WOLD, HERMAN, in association with LARS JUREEN, *Demand Analysis. A Study in Econometrics*, New York, John Wiley & Sons, Inc., 1953.
[16] WU, SHIH-YEN, AND JACK A. PONTNEY, *An Introduction to Modern Demand Theory*, New York, Random House, 1967.

A FURTHER REPLY

I took the original Canterbery-Bickel paper [1] seriously and made brief suggestions [5] designed to improve future effort. I will expand on the problem of interrelation between supply and demand for basic food grains in low income countries. An increase in production adds not only to supply but also to demand through its income effects [3, 4]. How much an increase in supply adds to demand depends on the income elasticities of demand of those who receive that income [2, 6]. Since the distributive bias of various new agricultural technologies varies greatly this is difficult to predict. Traditional labor-using technology may distribute 80 percent of the increments to income to low income agricultural laborers while new high-yielding varieties may distribute from nothing to 30 percent to the lower income laboring class [7].

However, associated with such new technologies may be employment programs which expand incomes of the laboring classes. We thus find a complex interplay of economic and political forces which determine income distribution and which have important consequences to the economic relationships that Canterbery and Bickel are studying.

Agricultural laborers in India, representing roughly the bottom two deciles in the income distribution, have expenditure elasticities of demand for food grains of about 0.8 and allocate about 55 percent of incremental expenditure to food grains. In contrast, owner-cultivators who lie approximately in the sixth, seventh, and eighth deciles in the income distribution, have expenditure elasticities of about 0.5 and allocate about 15 percent of incremental expenditure to food grains [7]. Thus, who gets the income has a substantial effect on the income elasticity of demand. It presumably influences the price elasticity as well.

The model used by Canterbury and Bickel is such that differences in assumptions of the order indicated here in income and price elasticities would substantially change the conclusions. In some countries application of new high-yielding varieties will almost certainly bring about changes in income distribution and hence in demand which will make simple application of past aggregate relationships inappropriate.

In other countries, the new agricultural technologies may not even be applied until a number of changes of this type are brought about. I am concerned, as I stated in my earlier comment [5], that "a high proportion of current (econometric) work assumes continuation of structural relationships which are themselves the antithesis of development."

JOHN W. MELLOR
Cornell University

References

[1] CANTERBERY, E. RAY, AND HANS BICKEL, "The Green Revolution and the World Rice Market, 1967–1975," *Am. J. Agr. Econ.* 53:285–294, May 1971.

[2] LELE, UMA J., AND JOHN W. MELLOR, "Jobs, Poverty and the Green Revolution," *Internat. Affairs* 48:20–32, Jan. 1972.

[3] MELLOR, JOHN W., *The Economics of Agricultural Development*, Ithaca, Cornell University Press, 1966, Ch. 4.

[4] ———, "Toward a Theory of Agricultural Development," in *Agricultural Development and Economic Growth*, eds., Herman M. Southworth and Bruce F. Johnston, Ithaca, Cornell University Press, 1967, pp. 21–61.

[5] ———, "Discussion," *Am. J. Agr. Econ.* 53:296, May 1971.

[6] ———, AND UMA J. LELE, "A Labor Supply Theory of Economic Development," Occasional Paper No. 43, Cornell University-USAID Employment and Income Distribution Project, June 1971.

[7] ———, "Domestic Markets and the Growth of Farm Cash Income," paper presented at the conference, "Agricultural Strategies for the 1970s: Their Design and Implication," Stanford, Calif., Stanford University, Dec. 13–18, 1971.

DISCRIMINATION IN THE MARKETS FOR FARM CAPITAL? COMMENT

The important question of discrimination in farm capital markets was raised in a recent paper by Tinney and Welch in this *Journal* [2]. Unfortunately, the hypothesis of discrimination was not fully explored by the authors prior to its rejection.

The authors assume that "in the presence of discrimination there is a difference in the cost of capital as viewed by Negro and white farm operators, and the interest rate used for decisions by Negro farm operators will exceed the rate used by white farmers" [2, p. 403]. Thus, they argue that evidence of higher rates of return to black-owned farm capital is necessary to support an hypothesis of discrimination. In the absence of significant differences in the rate of return for farms of equal size classes, Tinney and Welch conclude that discrimination does not exist in farm capital markets. They also find no return to education for black farm operators in contrast to the expected positive return for white education and that black farm operators are heavily concentrated in the smallest size category despite their reported equality in rates of return. Tinney and Welch argue, however, that these findings are consistent with their conclusion of nonexistence of discrimination in capital markets.

Two questions are to be raised with respect to the methodology and conclusions of Tinney and Welch's paper. First, we question the completeness of their model as a theoretical construction whose task is to indicate where and how discrimination is to be found. Second, based on the statistical results available in the paper, we question the validity of the authors' interpretation of these results.

The model of capital markets presented in this paper is so specified as to test only one means by which lenders can discriminate. They assume prejudices held by lenders will be monetized into higher interest rates. However, since usury laws impose an upper bound on interest rates, the prejudiced lender may not be adequately compensated at legal rates. In such cases, and also in general, the amount of collateral required for a given size of loan or even refusal to lend altogether are complementary means by which lenders can discriminate [1]. In fact, such nonprice rationing is an important dimension of capital markets even in the absence of racial prejudice since the banking industry's total output (as well as price range) is subject to external control by monetary authorities. Prejudice is at least as likely to effect perennially "tight" money markets for minorities as to erect a racial "tariff." Thus, discrimination by lenders must also be expected to take the form of smaller loans relative to a given amount of equity. Obviously, equality in rates of return is entirely consistent with this practice and is not a sufficient test for discrimination in farm capital markets.

The Farmers Home Administration, created as a lender of last resort to finance capital acquisition by small operators rather than the seasonal liquidity problems of farmers, requires borrowers to refinance through commercial sources if that alternative should become available. Thus, it seems reasonable to argue that if discrimination exists in this part of the market where the lending agent bears no personal risk, it is even more likely to exist in the private channels. In fact, the 1965 Civil Rights Commission's report on discrimination in federal agricultural services (to which Tinney and Welch refer in another context) clearly documents discrimination by the FHA in size of loan granted to black operators [3]. In each of six classes based on net worth, white borrowers received significantly larger loans both in absolute amounts and in the amount lent relative to equity. For example, in the two poorest classes, which contained

82 percent of the Negro borrowers in the 13 counties studied, the average loan was four times greater for whites than blacks. This discrimination in loan size is not limited to the 13 southern counties studied by the Civil Rights Commission. A national study [4] of new borrowers from the FHA in 1965–66 concluded:

> the financial size and equity of Negro farmers did not appear different enough to explain completely the substantially lower amounts of credit they obtained.

The unwillingness of Tinney and Welch to consider seriously the implications for their model of this aspect of lender discrimination is all the more startling given two results of their own study. They do acknowledge that discrimination in the availability of capital is indeed consistent with their finding that Negroes operate smaller farms than do whites despite insignificant differences in their rates of return within size classes. They also admit that the inability of blacks to obtain capital is suggested by their reported dichotomy between the races on returns to education. Nonetheless, Tinney and Welch dismiss the subject of loan-size discrimination by stating that due to "intermediation possibilities we find an argument in favor of discrimination in capital markets to be unconvincing, and the data *are* [sic] consistent with this hypothesis" [2, p. 406]. In fact, this alleged consistency can refer only to interest rate discrimination, for the same data are quite consistent with an hypothesis of discrimination in availability of capital. But most important, for the authors simply to introduce the contradiction posed by loan-size discrimination and then just to *assume* that the possibility of intermediation renders discrimination unlikely is hardly a sufficient test for the presence or absence of the phenomenon under investigation. The context of this quotation suggests that the troublesome question of loan-size discrimination raised by their data is thus dismissed; however, it hardly bears mentioning that the introduction of such an assumption reduces the question of *both* types of discrimination to a trival exercise. For if the authors can assume that intermediation precludes the possibility of loan-size discrimination, it is up to them to show why it is not equally applicable to discrimination in interest rates.

Assuming now that the model developed by Tinney and Welch is a correct specification of the farm capital market, do their statistical results unquestionably support their conclusions? The relevant coefficients (regression equation 1) are reproduced here for the sake of discussion. Considering Classes 1 and 2, Tinney and Welch tell us that the regression coefficients for blacks are higher than those for

	Class 1	Class 2	Class 3
White	3.40 (.25)*	2.00 (.78)	.30 (.94)
Negro	4.60 (18.55)	5.40 (5.40)	−.30 (2.91)

* Numbers in parentheses indicate standard errors.

whites, although "a question of significance of the differences remains." In all likelihood (no covariance of coefficients is available in the paper to perform tests), given the large standard errors for the coefficients referring to blacks, 4.6 is not statistically different from 3.40, and likewise for 5.40 and 2.00. In fact the white-Class 1 coefficient could be much higher than 4.60 in value (assuming the same standard error) and still be no different from 4.60 in the statistical sense. Further, it is interesting to note, since Tinney and Welch failed to do so, that for both classes (1 and 2) the coefficients referring to whites are different from zero while those referring to blacks are *not*. If we are to take the authors' model seriously, this means that in the farm capital market there exists discrimination against white farm operators! Despite these difficulties the authors proceed and impose on regression 1 the restriction that within classes the rate of return is the same for black and white operators. The corresponding F-test fails to reject the hypothesis that the restriction is valid. In light of the previous discussion this should be expected. We suspect that the F-test would also give the same result for other linear restrictions, for example, that the rate of return for blacks is higher than that for whites by five units.

The general idea in this discussion is that the standard errors of the coefficients of blacks are so high that no reliable conclusion can be drawn about equality of rates of return for blacks and whites.

In conclusion, we find the analysis by Tinney and Welch of the farm capital market unsatisfactory on two grounds: first, their model is misspecified because it ignores a dimension of the capital market in which racial discrimination is [or may be] practiced, i.e., nonprice capital rationing, which may be at least as important as the price dimension; second, the presented statistical evidence provides no suggestion in relation to the questions of existence of discrimination. Thus, the authors' conclusion (among other things) that investigation of the relationship between black-white income differentials in farming and capital markets may not be fruitful is not justified.

THEODORE P. LIANOS
EDITH HALL PARKER
University of California, Davis

References

[1] ALHADEFF, DAVID A., *Monopoly and Competition in Banking*, Berkeley, University of California Press, 1954.

[2] TINNEY, ROBERT, AND FINIS WELCH, "Discrimination in the Markets for Farm Capital?" *Am. J. Agr. Econ.* 53:401–410, Aug. 1971.

[3] U.S. Commission on Civil Rights, *Equal Opportunity in Farm Programs*, Washington, D.C., 1965.

[4] U.S. Department of Agriculture, *New Borrowers in the Farmers Home Administration Operating Loan Program, 1965/1966*, ERS, Agr. Econ. Rep. 160, May 1969.

DISCRIMINATION IN MARKETS FOR FARM CAPITAL? REPLY

We are a bit confused as to the nature of the Lianos-Parker objections with our interpretation of results. We quote first from their comment, and then from the original paper. Lianos and Parker state:

> In the absence of significant differences in the rate of return for farms of equal size classes, Tinney and Welch conclude that discrimination does not exist in farm capital markets [1].

They go on to suggest that discrimination may not be in terms of higher interest charges for equal loans (presumably with equal equity collateral), but that discrimination may take the form of loan prohibition. That is, the marginal supply price may be infinite. The implication is that we did not explore this possibility.

In fact, our interpretation of results is that,

> The evidence is that rates of return vary with farm size and that they increase as size increases. Negroes earn lower returns than whites, not because returns differ within scale classes, but because Negroes operate smaller farms. Is this evidence of discrimination? The answer is a somewhat timid 'No, but discrimination is consistent with the observation.' Strong evidence of discrimination requires evidence of Negroes earning higher returns than whites. If returns increased with farm size and capital were more of an inhibiting factor for Negroes (i.e., there is discrimination) in their attempts to expand, we would expect to see Negro operators 'pushing harder' against the capital constraint, that is, earning higher returns within size classes. This evidence is missing. On the other hand, the evidence is consistent with an hypothesis of no discrimination, but this interpretation presents the question of why Negro farms have not attained the same 'size' as white farms. What we can conclude is that the market has not operated to permit an observation of the kind of discrimination described in the model presented earlier. This may be either because there is in fact no discrimination or because discrimination has been more 'prohibiting' in the sense that charges precluded borrowing rather than being merely 'slightly' higher rates. The type of data described here cannot go further in breaking into this 'box' . . . . [2, p. 406]

The main point of the Lianos-Parker argument appears to be that we simply failed to place adequate stress on the possibility of exclusion as a discriminatory practice. We obviously discussed the possibility, but noted that our data were inadequate for addressing the problem. In that context we saw no point in very detailed speculation. The real problem is not that discrimination takes one or the other form, for analytically they are the same. That is, *ceteris paribus*, in either case the supply price of funds is higher to Negroes. The distinction is empirical.

The advantage of the approach we used is that we focused only upon earned rates of return. This avoids the very substantial problems of risk adjustments, etc., that would be necessary had we referred to direct evidence from loan institutions. But to use the indirect evidence of earned returns we must have data. If discrimination results in exclusion, then we simply do not have data for inferring what would have been earned had the loan been granted.

ROBERT TINNEY
Pennsylvania State University
FINIS WELCH
National Bureau of Economic Research

References

[1] LIANOS, THEODORE P., AND EDITH HALL PARKER, "Discrimination in the Markets for Farm Capital? Comment," *Am. J. Agr. Econ.*, this issue.

[2] TINNEY, ROBERT, AND FINIS WELCH, "Discrimination in the Markets for Farm Capital?" *Am. J. Agr. Econ.* 53:401–410, Aug. 1971.

EVALUATION OF INDIAN FERTILIZER PROJECTS: AN APPLICATION OF CONSUMER'S AND PRODUCER'S SURPLUS: COMMENT*

Tintner and Patel considered the welfare implications of the use of fertilizers in Indian agriculture in previous *Journal* articles [2, 3]. They specified a demand function of the form

$$p = a - bq \tag{1}$$

where p is price of agricultural output (rice or wheat) and q is quantity of output demanded per capita. The supply function was assumed to be price inelastic and of the form

$$q = c + ds \tag{2}$$

where q is quantity (rice or wheat) supplied per capita and s is quantity of fertilizer used per capita. Total surplus, i.e., consumer's plus producer's surplus, at market equilibrium was defined as the area under the demand curve up to the fixed quantity supplied as determined by fertilizer application. Total surplus was maximized with respect to the quantity of fertilizer used per capita. The authors concluded that total surplus in both rice and wheat can be increased with more fertilizer. However, more

* I am very grateful to Dr. S. C. Littlechild for helpful comments.

Table 1. **Rice: comparison of the total surplus-maximizing equilibrium with the 1963–64 equilibrium***

	Total surplus-maximizing	1963–64	Units
s	.019442	.004989	quintals/capita
p_o	5.734655	41.383613	*Rs.*/quintal
q_o	1.339337	0.812981	quintals/capita
$R_n(s)$	64.366877	54.984296	*Rs.*/capita
Producer's surplus	7.680636	33.644091	*Rs.*/capita
Consumer's surplus	56.686241	21.340205	*Rs.*/capita

* The 1963–1964 equilibrium price and quantity are obtained by using the demand and supply functions estimated by Tintner and Patel.

Table 2. **Wheat: comparison of the total surplus-maximizing equilibrium with the 1963–64 equilibrium***

	Total surplus-maximizing	1963–64	Units
s	.011238	.001894	quintals/capita
p_o	7.196538	40.190709	*Rs.*/quintal
q_o	.524358	0.253279	quintals/capita
$R_n(s)$	18.159699	13.672229	*Rs.*/capita
Producer's surplus	3.773562	10.179463	*Rs.*/capita
Consumer's surplus	14.386137	3.492766	*Rs.*/capita

* The 1963–1964 equilibrium price and quantity are obtained by using the demand and supply functions estimated by Tintner and Patel.

than 4.36-fold and 6.99-fold increases in use of fertilizer for rice and wheat,[1] respectively, lead to decreases in total surplus.

This outcome obtained by Tintner and Patel is valid only if the marginal cost of fertilizer application is zero. It can be shown that the maximization of total surplus, as defined by Tintner and Patel, gives welfare maximizing equilibriums with zero prices for rice and wheat. This outcome corresponds to the result that when marginal cost is zero, total surplus is maximized at zero equilibrium price. Since the cost of fertilizer application will usually be positive, maximization of total surplus net of the marginal cost of fertilizer application is illustrated below.

The net consumer's and producer's surplus, $R_n(s)$, is defined as[2]

$$R_n(s) = \int_0^{q_o = c + ds} (a - bq)dq - ks \tag{3}$$

where k, a positive constant, denotes the marginal cost of applying fertilizer.

$R_n(s)$ is maximized when

$$s = \frac{ad - bcd - k}{bd^2} \tag{4}$$

and

$$p_o = \frac{k}{d}. \tag{5}$$

Since $1/d$ units of fertilizer are required to produce an additional unit of output, (5) is the familiar requirement that price must equal marginal cost for maximum total surplus.

The total surplus maximizing values of s, q_o, and p_o have been computed using the demand and supply functions estimated by Tintner and Patel.[3] For rice, these are

$$p = 96.445064 - 67.727845\, q$$

and

$$q = 0.631289 + 36.418487\, s,$$

and for wheat they are

$$p = 71.018367 - 121.714227\, q$$

and

$$q = 0.198332 + 29.011\, s.$$

The marginal cost of applying fertilizer, $k = 208.81$ *Rs*/quintal, is taken from Herdt and Mellor [1, pp. 156–157]. This cost is the sum of the price of fertilizer and handling, harvesting, and credit costs. The price is for the agricultural year 1963–64. The rest of the costs are for 1961–62 but are assumed to hold for 1963–64. The results are presented in Tables 1 and 2. A 3.9-fold increase in fertilizer application per capita for rice and a 5.93-fold increase for wheat are found to be optimal.

The market equilibrium for both these commodities is very far from achieving maximum total surplus. This may be due to resistance against innovation, a rapid shift of the demand curve upwards, or a combination of these two factors. For the producers, the 1963–64 equilibrium yields much higher surpluses than the total surplus-maximizing equilibrium for the given demand functions. Unless the demand functions shift upwards sufficiently rapidly, movement to total surplus-maximizing equilibrium would

[1] The optimum increases required are multiples of the per capita quantity of fertilizer used in the year 1963–64.

[2] Note that in general there may be fixed costs (i.e., farmers' production costs invariant with changes in quantity of fertilizer applied). Their omission here will have no effect on the optimum s, p_o, and q_o. The actual optimum $R_n(s)$ will however be the $R_n(s)$ obtained by maximizing (3) less fixed costs. The burden of fixed costs will fall entirely on producer's surplus.

[3] The coefficients are adjusted so that q and s are quintals per capita and p and k are in *Rs.* per quintal.

have to occur through increased fertilizer application or other technological changes to be introduced by producers over a period of time when their expectations of future surpluses or prices may be falling. This problem is not within the scope of this comment, but policy makers may soon have to start paying more attention to it.

KIRIT G. VAIDYA
Graduate Centre for Management Studies
Birmingham, England

References

[1] HERDT, ROBERT W., AND JOHN W. MELLOR, "The Contrasting Response of Rice to Nitrogen: India and the United States," *J. Farm Econ.* 46:150–61, Feb. 1964.

[2] TINTNER, GERHARD, AND MALVIKA PATEL, "Evaluation of Indian Fertilizer Projects: An Application of Consumer's and Producer's Surplus," *J. Farm Econ.* 48:704–710, Aug. 1966.

[3] ———, "Evaluation of Indian Fertilizer Project: An Application of Consumer's and Producer's Surplus: Correction," *J. Farm Econ.* 49:527, May 1967.

A LOW-COST SPATIAL EQUILIBRIUM SOLUTION PROCEDURE*

The search for more efficient computational procedures for solving interregional trade problems has occupied the time and energy of a goodly number of agricultural economists in recent years. For some reason, the proposal made by the late T. E. Tramel and A. D. Seale, Jr. [11] at the annual meeting of our association at Cornell University in 1959 has been largely ignored. The purpose of this communication is to report our recent experience with reactive programming in the hope that others will find it equally attractive as an analytical tool.

Successful applications of this model in 1959 and 1960 were reported in [1], [5], and [6] and further elaborated in the proceedings of a 1963 workshop [7, 12]. Upper limits may be placed on one or more supply areas, marginal revenue curves may be substituted for demand curves, two products may be considered simultaneously, and either linear or log-linear functions may be used. With minor modifications of the Tramel program other functional forms are equally suitable. The formulation is thus much more flexible than is a quadratic programming one.

More complicated problems have been analyzed using this general framework. Of particular interest is the recent study of tariff and reference price policy by Zusman, Melamed, and Katzir [13]. Their discussion of alternative models found in Appendix A [13] is especially valuable.

In a 1963 paper comparing quadratic programming methods with several gradient methods, Takayama and Judge [8, p. 18] concluded, "Since the (gradient) methods are designed for approximate solutions, exact solutions can be obtained only after an infinite number of iterations. Thus getting the exact solution will require a hopelessly large amount of computer time." This same statement is to be found in the book recently published by these authors, [9, p. 497]. However, this evaluation of reactive programming was disputed in a reply by Tramel [10] and is not consistent with our experience.

Rapid development of computer hardware and minor modification of the Tramel computer program may be partially responsible for this difference in viewpoint. As indicated above, the reactive programming algorithm requires that an initial set of supply and demand quantities be provided. We have inserted in the Tramel program a routine which calculates the equilibrium price for the system on the assumption that transfer costs are zero, computes the appropriate quantities for the initial allocation, and proceeds immediately to calculate the desired equilibrium solution. Another modification builds on Tramel's scheme to allow the operator to specify the degree of accuracy desired. The computer first solves the problem with rough accuracy, say one cent per unit, and then modifies this solution to produce a result with as fine a degree of accuracy as may be desired or as the initial data base warrants. Copies of this program are available to interested parties.

Computer time requirements for reactive programming models will vary among installations. Some 12 years ago a problem having logarithmic functions for 22 markets and 18 supply areas required one and a half hours on the IBM 650 [11, p. 1018]. Six years later the computer program described in [10, pp. 41–52] solved a 36 supply area-42 market problem having fixed supplies in four minutes on an IBM 7040 and in 15 seconds on an IBM 7090 [10, p. 16]. The current NCSU program using the WATFIV compiler on the IBM 360 provided the solution to the Hsiao-Kottke [4] problem consisting of 13 supply areas and 12 markets in five seconds at a cost of something like $1.25.

Of more interest to many users is the ease of data preparation. For reactive programming, one card is prepared for each demand function and one card for each supply function. Transfer costs are read in five

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routes per card. Desired levels of accuracy are specified and upper limits on supplies are indicated where appropriate. The computer takes over from there, providing equilibrium parameters at each accuracy level. Standard quadratic programming tableaus are of the order $(n^2+2n)\times 2(n^2+2n)$, which amounts to some 65,000 elements for the 13×12 Hsiao-Kottke problem and 657,000 elements for the 23×21 Dhillon [3] problem, although most entries are zero and some solution procedures use a slightly smaller matrix. In contrast, transfer cost elements required in the reactive programming formulation number 156 and 483 for these same problems.

A word on the teaching of reactive programming may be in order. What may sound like a fairly complicated topic is now one of our fun sessions. To play the game, students are assigned to every supply area. Each supplier in turn makes his initial decision on total output and allocation among markets. Each market manager then reports what he will pay as established by his demand function. Supplier A then reconsiders his first selections, given the behavior of the other players. Market managers respond with a new set of prices and Supplier B is allowed to adjust his previous selections. While full convergence likely would take more time than is available in the usual class period, the process by which an equilibrium is reached becomes clear after a few iterations. Some sample problems for class use are reproduced in Bressler and King [2, pp. 100–106].

In summary, we find the reactive programming format is simple to formulate and easy to use for a wide variety of interregional trade problems. It is inexpensive in terms of computer time required. The computer program provides output in a format that is easy to interpret. It is flexible in terms of functional forms of demand and supply relations that can be selected. It has been well tested and is known to be mathematically sound. What more can one ask of a spatial equilibrium algorithm?

FOO-SHIUNG HO
Virginia Polytechnic Institute and State University
RICHARD A. KING
North Carolina State University

References

[1] ALLEN, M. B., AND A. D. SEALE, JR., *An Evaluation of the Competitive Position of the Cabbage Industry in Mississippi and Competing Areas*, Mississippi Agr. Exp. Sta. AEc Tech. Pub. No. 2, Sept. 1960.

[2] BRESSLER, RAYMOND G., JR., AND RICHARD A. KING, *Markets, Prices and Interregional Trade*, New York, John Wiley & Sons, Inc., 1970.

[3] DHILLON, PRITAN, *Milk Production and Demand in the Northeast*, New Jersey Agr. Exp. Sta. Bull. 826, Oct. 1969.

[4] HSIAO, JAMES C., AND MARVIN W. KOTTKE, *Spatial Equilibrium Analysis of the Dairy Industry in the Northeast Region—An Application of Quadratic Programming*, Storrs (Conn.) Agr. Exp. Sta. Bull. 405, July 1968.

[5] SEALE, A. D., JR., AND M. B. ALLEN, *Reactive Programming of Supply and Demand for Watermelons Produced in Mississippi and Competing Areas*, Mississippi Agr. Exp. Sta. AEc Tech. Pub. No. 1, June 1959.

[6] ———, *An Evaluation of the Competitive Position of the Snap Bean Industry in Mississippi and Competing Areas*, Mississippi Agr. Exp. Sta. AEc Tech. Pub. No. 3, Dec. 1960.

[7] SEALE, A. D., JR., AND T. E. TRAMEL, "Reactive Programming Models," in *Interregional Competition Research Methods*, ed., Richard A. King, Raleigh, Agricultural Policy Institute Series No. 10, North Carolina State University, 1965, Ch. 4, pp. 47–58.

[8] TAKAYAMA, T., AND G. G. JUDGE, *Non-Linear Formulations of Spatial Equilibrium Models and Methods for Obtaining Solutions*, Illinois Agr. Exp. Sta. AERR 66, in cooperation with the Farm Economics Research Division, ERS, USDA, Nov. 1963.

[9] ———, *Spatial and Temporal Price and Allocation Models*, Amsterdam, North-Holland Publishing Company, 1971.

[10] TRAMEL, THOMAS E., *Reactive Programming—An Algorithm for Solving Spatial Equilibrium Problems*, Mississippi Agr. Exp. Sta. AEc Tech. Pub. No. 9, Nov. 1965.

[11] ———, AND A. D. SEALE, JR., "Reactive Programming of Supply and Demand Relations—Application to Fresh Vegetables," *J. Farm Econ.* 41:1012–1022, Dec. 1959.

[12] ———, "Reactive Programming—Recent Developments," in *Interregional Competition Research Methods*, ed., Richard A. King, Raleigh, Agricultural Policy Institute Series No. 10, North Carolina State University, 1965, Ch. 5, pp. 59–68.

[13] ZUSMAN, PINHAS, ABRAHAM MELAMED, AND ITZHAK KATZIR, *Possible Trade and Welfare Effects of EEC Tariff and "Reference Price" Policy on the European-Mediterranean Market for Winter Oranges*, Berkeley, California Agr. Exp. Sta., Giannini Foundation Monograph 24, Sept. 1969.

A MARKET-SHARE APPROACH TO THE FOREIGN DEMAND FOR U.S. COTTON: COMMENT

Sirhan and Johnson [1] have argued that a market-share model of cotton imports to major importing countries would provide a good basis for estimating export and import demand elasticities. They describe the conditions in which use of such a model would be appropriate: "Each exporting country, hence, is to some degree a 'price maker' in an import market but differs from the 'pure monopolist' in the sense that its cotton exports have close, but not perfect substitutes" [1, p. 594]. I will argue that these important conditions were *not* satisfied during the period covered by their analysis, 1953–1966, and that because of the conditions that did prevail, an excess-demand or residual-supplier model would have been a more appropriate basis for gaining insight into the elasticity of demand for exports.

With some minor exceptions the U.S. effectively set the world price for cotton throughout 1953–1966. During this period the U.S. fixed its export price of cotton a year at a time, exported substantial quantities of cotton in every year, and maintained large CCC stocks during almost all of this time. Except for brief periods, the CCC stocks were large enough to leave no doubt that the total world demand for cotton at the U.S. export price would be satisfied by current U.S. production, foreign production, and carryover stocks.

Because of the nature of the institutions and the world markets for cotton during these years, there is reason for expecting a close relationship between the minimum price at which the CCC would make cotton available for export and the world price. Table 1 and Figure 1 suggest that the two price series were indeed closely correlated during 1953–1966 ($r=.96$). It is surprising that the correlation is as close as it is, considering there were several major changes in U.S. policy during this time. Also, one price series is quoted on a crop-year and the other on a calendar-year basis. There were brief periods during which the CCC stocks dropped low enough to create substantial, although shortlived, increases in the spread between the two prices.

If Sirhan and Johnson had been aware of how completely the world price of cotton during 1953–1966 was dominated by U.S. cotton export policy, they would certainly not have stated, "One may attribute the downward movement in cotton prices (during 1953–1966) to relative increases in available supplies of both cotton and man-made fibers" [1, p. 594]. In fact, the U.S. lowered its effective export price and with it the world price rather than suffer

Table 1. Average price c.i.f. Liverpool, support price, export subsidy rate, and "export price" for U.S. Middling one-inch cotton, 1953–66

Year	Price c.i.f. Liverpool[1] (1)*	Domestic support price[2] (2)**	Export subsidy payment (3)**	U.S. "export price" (4)†
		(cents per pound)		
1953	38.42	33.50		33.50
1954	39.13	34.03		34.03
1955	38.91	34.55	7.50[4]	32.67
1956	33.17	32.74	7.21[4]	25.53
1957	30.62	32.31	6.19[4]	26.12
1958	30.48	35.08	6.50	28.58
1959	26.92	34.10A[3] 28.40B[3]	8.00	23.25
1960	27.03	32.42A[3] 26.63B[3]	6.00	23.52
1961	28.81	33.04	8.50	24.54
1962	28.62	32.47	8.50	23.97
1963	27.29	32.47	8.50	23.97
1964	26.96	30.00	6.50	23.50
1965	26.75	29.00	5.75	23.25
1966	25.40	21.00		21.00

[1] Simple average of monthly prices in each calendar year.
[2] Based on a crop year which begins August 1 of the year that the crop is grown and ends following July 31.
[3] A—Loan rate for growers who participated in Plan A of Agricultural Adjustment Act of 1958 under which harvested acreage could not exceed the allotment. B—Loan rate for growers who participated in Plan B under which the harvested acreage could exceed the allotment by 40 percent.
[4] Difference between CCC export sale price and average price for Middling one-inch cotton in the designated spot markets.
* ERS, USDA, *Cotton Situation*, various issues.
** ERS, USDA, *Cotton Production and Farm Income Estimates Under Selected Alternative Farm Programs*, Agr. Econ. Rep. 212, Sept. 1971.
† Col. 2 minus Col. 3 except for 1955. Since the export subsidy program was only in effect for the last three months of the 1955 crop year, only one-fourth of export subsidy was subtracted from the support price.

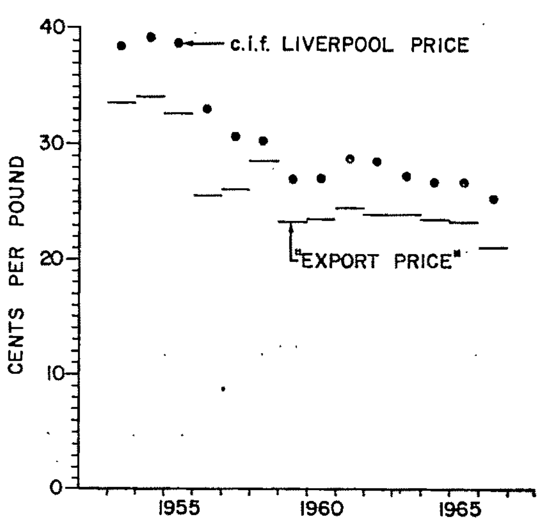

Figure 1. Average price c.i.f. Liverpool and "export price" of U.S. Middling 1-inch cotton, 1953–66. Source: Table 1.

the consequences of declining export markets, which would have been the result of maintaining the high export price.

Figure 1 suggests that the U.S. through its policies was an almost absolute "price maker" during 1953–1966, at least for the general level of world prices. The "price maker" role of other exporting countries was effectively limited to influencing the differential between the export price of their cotton and the U.S. export price.

The extent of price-making power of other exporting countries depends on the extent to which their cotton is regarded in the market place as a less than perfect substitute for cotton grown elsewhere. This relationship is measured by the elasticity of substitution. If the measured elasticity is essentially infinite, then exporting countries other than the U.S. had virtually no price-making power and the market-share model becomes meaningless.

If a legitimate statistical test could be carried out, it appears to me that the elasticity of substitution of (−)10 or (−)20 as measured by Sirhan and Johnson would not differ significantly from infinity. Even if it were significantly different in a statistical sense, it does not appear to me that there is a meaningful difference between the measured elasticities of substitution and a value of infinity at a practical level. With a value of (−)10 the market share would drop from 100 percent to zero with a 10 percent increase in the price ratios through the appropriate range. With a value of (−)20 only a 5 percent increase in the price ratio is needed to accomplish the same thing.

In any case, it seems to me that the elasticity of substitution is so high that for most policy considerations cotton in the world market should be considered a homogeneous product. To the extent that the market has differentiated the value of cotton grown in different countries, this has a small effect on relative prices but has very little to do with shares of the world market for cotton. To the extent that the policies of various governments allow it to operate, ultimately the law of comparative advantage will determine market shares in the case of several countries producing a homogeneous or near homogeneous product.

ROBERT S. FIRCH
University of Arizona

Reference

[1] SIRHAN, GHAZI, AND PAUL R. JOHNSON, "A Market-Share Approach to the Foreign Demand for U.S. Cotton," *Am. J. Agr. Econ.* 53:593–599, Nov. 1971.

A MARKET-SHARE APPROACH TO THE FOREIGN DEMAND FOR U.S. COTTON: REPLY

Professor Firch feels that Sirhan and I have misspecified the world market for cotton. His evidence is a close correlation between the U.S. export price and the c.i.f. Liverpool price. I do not think this evidence is sufficient. In the statistical series used for our analysis, one finds trends and fluctuations in both the U.S. market share and the ratio of U.S. prices to other prices (after standardizing for grade). If the market really viewed all cotton as homogeneous, and if adjustments were instantaneous (which also seems necessary for the Firch argument), then only one price would prevail; there would be no fluctuations in price ratios and the ones we observed must be statistical artifacts of the way data are collected or reported. Sirhan and I simply assumed the data did not represent a collection of such artifacts. The model we used seemed to contain a reasonable explanation of events; the results were plausible and interesting. We would be happy to reconsider the specification if someone shows us where the data are misleading.

I suppose it is not quite enough to appeal to the positivistic result. Even if one adopts the view that assumptions need not be "realistic," he should not adopt a model of a market widely at variance with the workings of the market. Two observations seem in order here.

In a market with a large dominant supplier, competing suppliers can adopt pricing strategies that could nibble away at the dominant supplier's share. Professor Firch is quite right—the U.S. did dominate the world cotton market in the period under consideration. But in my opinion, his statement that "the U.S. lowered its effective export price and with it the world price rather than suffer the consequences of declining export markets . . . " says the same thing as our analysis—that market shares are a function of the price ratios.

Secondly, I can think of several institutional and political reasons why the world cotton market views competing supplies as less than perfect substitutes or why adjustments are less than instantaneous. Either or both of these conditions are sufficient to observe different prices at a moment of time. As sellers of aspirin know well, one need only think that qualities differ for short-run price differences to exist; actual qualities need not differ.

Finally, one aspect of the study to which the

reader is only casually alerted is employment of the market-share model as an experiment in deriving export demand elasticities in an indirect manner.[1] As is well known, direct estimates of these elasticities typically result in estimates that are much too low. Thus, the market share and substitution elasticities both go in the direction Sirhan and I anticipated; the demand facing the U.S. is more elastic than a direct estimate based on the U.S. quantity exported would indicate. In this vein, Firch's use of the estimated substitution elasticity is not warranted. By well-known statistical principles, the estimates reported are only valid in the neighborhood of the data. For the reasons given in our original article, we do not expect market shares to go to zero. The price and quantity changes one observes are marginal, and nothing so dramatic as a disappearance of the U.S. market share is explainable by any equilibrating type model.

[1] In fact, cotton and the market-share model are only one of several studies that have been concerned with indirect estimation of export elasticities. These studies are summarized in [1].

PAUL R. JOHNSON
North Carolina State University

Reference

[1] JOHNSON, PAUL R., "Studies in the Demand for U.S. Exports of Commodities," Raleigh, North Carolina State University, Dept. of Economics, Economics Res. Rep. 15, Feb. 1971.

Reviews

Arthur, Henry B., *Commodity Futures as a Business Management Tool*, Division of Research, Graduate School of Business Administration, Boston, Harvard University, 1971, xiv + 385 pp. ($10.00)

Reading this book was an exhilarating experience for this reviewer who has always felt that somehow futures markets are more than "generators of a statistical price configuration" which satisfy the random walk hypothesis or social institutions which permit the study of decision making under uncertainty. This is not to say, of course, that these are considerations unworthy of attention, because they clearly merit continuing study. It is to say, however, that we should not lose sight of another relevant question pertaining to these social institutions, namely, how may those firms involved in handling the physical commodities represented by trading on these markets use them as an adjunct to their individual business operations? This is the question which Professor Arthur sets out to answer. Perhaps the perspective of this book is best stated by Arthur himself in the opening sentences of the first chapter:

> Most of the past studies of commodity futures markets have dealt primarily with the operation of the futures markets themselves and with various characteristics of price behavior on these markets. The present study examines the uses of commodity futures markets by the businesses which produce, handle, process, and market those important agribusiness commodities for which there are organized futures exchanges.

The book is organized into four major parts. The first two place futures markets in the general context of commodity inventories, inventory management, risk exposure, and risk management, with primary emphasis on the individual firm. Part Three presents a detailed discussion of the uses made of five commodity markets: wheat (Chapter V), soybeans (Chapter VI), cattle (Chapter VII), cocoa (Chapter VIII), and frozen concentrated orange juice (Chapter IX). These chapters are particularly important because they present material obtained from interviews with 86 firms and agencies associated with some aspect of the production and marketing of these commodities. These chapters clearly demonstrate the considerable flexibility that futures markets offer to the individual firm. A careful reading of them will provide many valuable suggestions to those who are either actively involved in the firm's decision-making process or who provide an advisory or educational service to individual firms. The final part presents an overall summary with general suggestions for policy applications.

As already suggested, the basic strength of the book is derived from its emphasis on the uses which the individual firm can make of a futures market. But it goes beyond this. Arthur takes a major step forward in debunking the myths surrounding futures markets and hedging that have been perpetrated in conventional textbooks on agricultural marketing. Firms do not blindly and automatically hedge; hedging does not *eliminate* risk; firms use futures markets for purposes other than to shift risk; an optimal policy for one firm is not necessarily the optimal policy for another firm; the structure of the industry, the type of economic activity in which the firm is involved, and its objectives concerning risk management are important determinants of the uses it will make of the futures market. Certainly these ideas are not new; one only need call to mind the writings of Holbrook Working. Nevertheless, this book makes a real contribution because it presents these ideas in one place, documents their relevance with information obtained from firms "out there" in the real world, and, finally, adds a new aspect—the desirability of an articulation of the firm's policy with regard to risk management and the need for a management information system to assure that the policy objective is being achieved. It is the latter which is novel and which, for this reviewer, makes this book required reading for those who are seriously concerned with assisting firms to develop, implement, and monitor policies relating to the use of a futures market.

The major weakness of the book stems from its novel contribution, the integration of risk management policy and the accounting system used as a monitoring device. For one whose knowledge of accounting procedures is minimal, as may be the case for many of us trained in economics, it is difficult to appreciate fully what is being discussed. Perhaps it is not important that the reader be provided with everything within one set of covers, but it would certainly have made the book more useful as an operating manual if liberal use had been made of specific illustrations at the appropriate points in the text.

A second source of considerable concern is the author's "theory of analogous part." This part of the book was read several times and engendered several discussions with colleagues in an attempt to deter-

mine whether anything new was presented or whether it was simply an alternative, and somewhat confusing, way of viewing the traditional idea of trading on the basis. Some specific illustrations of this concept carrying a hedging operation through to completion would have been most helpful. It seems revealing, at the conceptual level, to decompose the basis into two components, one associated with the general price level and one associated with situations unique to the individual trader. However, it was not possible for this reviewer to make the concept operational in the sense implied by the author. This may, however, reflect the naiveté of the reviewer concerning actual hedging activities rather than the complexity of the theory presented.

Overall, this is a good book and must be included in the library of those professional people who are involved with risk management problems of agribusiness firms. One can only conclude that more work must be done along these lines—hopefully Arthur will continue the work he has started, particularly by extending the integration of risk management and the requisite management information systems.

A. C. Johnson, Jr.
University of Wisconsin

Blase, Melvin G., ed., *Institutions in Agricultural Development*, Ames, Iowa State University Press, 1971, xxii + 247 pp. ($5.95)

This volume, prepared by the International Rural Institutions Subcommittee of the North Central Land Economics Research Committee, is the result of a project initiated in 1967. Chapter One opens with a brief discussion of the urgent need for world agricultural development in view of the population/food balance problem, stresses the complexity of the development process, and establishes the objective of the book to be a "... comprehensive view with respect to the most important institutions [affecting agricultural development]." The remaining 10 chapters comprising the volume cover the institutional waterfront, including land tenure, factor and product markets, planning, teaching, research, extension, credit, government, and legal institutions. The focus is upon the role of these institutions in the developing nations, and the technique employed is to commission one author for each chapter and to follow this major paper with two discussants.

Students of economic development and others will be quite familiar with the names and the work of most of the contributors. A great deal of international experience in agricultural development is represented by the group. It is difficult, however, to prepare such a wide-ranging volume when each of the topics could be (and have been) the subject of entire books. Space constraints require either a rather broad brush treatment or a focus upon certain selected aspects to the exclusion of other, perhaps equally important, aspects. The quality of the chapters is quite variable, ranging from excellent to mediocre. Some of the authors apparently found it impossible to grapple meaningfully with the broader institutional issues inherent in their assigned topics and attempted to resolve their dilemma by simply cataloging problems, needs, procedures, etc., without making the necessary effort to tie the package together in a conceptual framework to provide the reader with something to take hold of. And some of the discussants, as discussants are wont to do, have tended to strike out on their own, largely ignoring the mother paper—but in so doing occasionally providing some rather stimulating insights.

Being experienced internationalists, most of the authors issue the now conventional warnings: (1) don't attempt wholesale transplants of U.S. institutions to the socioeconomic, political, and cultural environment of the developing country, (2) don't consider any single constraint as *the* limiting factor to development; stress the complex interdependencies, the package approach, etc., and (3) don't attempt to create any broadly applicable recipe for development; stress instead the need for an intimate knowledge of the individual country setting. Many of the authors make a bow in the direction of the need for interdisciplinary efforts, but little evidence of this approach being seriously tested is offered to the reader.

The volume itself, however, provides an excellent example of how the insights of various disciplines may be brought to bear upon a problem area. Although heavily weighted in the direction of economics, there are also contributions from the fields of law, political science, and agronomy.

Despite the unavoidable problems inherent in tackling such a comprehensive topic, the end result is a highly readable volume which the development-oriented researcher and teacher will find well worth adding to his library. Many of the chapters include substantial bibliographies, and almost every chapter provides at least a few thought-provoking insights into the development process. By picking and choosing, the teacher of development could make good use of various chapters of this book as a point of departure to stimulate class discussions of the role of institutions in agricultural development; and the practitioner might become more aware of some of the developmental pitfalls that await the unwary.

Russell H. Brannon
University of Kentucky

Chao, Kang, *Agricultural Production in Communist China 1949–1965*, Madison, The University of Wisconsin Press, 1970, xv + 357 pp. ($15.00)

Myers, Ramon H., *The Chinese Peasant Economy: Agricultural Development in Hopei and Shantung, 1890–1949*, Cambridge, Harvard University Press, 1970, ix + 394 pp. ($12.00)

These are two very important books on Chinese agriculture which should be read by all interested in

this subject. Myers' study presents the problems which confronted China before 1950; Chao's study shows how these problems were tackled under the communist government after its control of the mainland in 1950.

The main body of Myers' study falls into two parts. In the first part, the author provides detailed descriptions of four villages in North China (Hopei and Shantung provinces) with particular reference to land, capital, land tenure, labor, credit, peasant incomes and savings, land inheritance, village leadership and organization, and village and county finance. The second part generalizes some of the characteristics of China's rural economy in the light of findings from the four case studies with special reference to labor, capital and technology, labor utilization and commercial development, changes in peasant living standards, the relationship between landlord and peasants, and the role which moneylenders, merchants, and bureaucrats played in the rural economic system. The study was based primarily on surveys made by Japanese researchers of the South Manchurian Railroad Company between 1939 and 1940.

As a whole, I found Myers' study more provocative than penetrating. It is provocative in demonstrating among other things what one can do with the wealth of data on Chinese agriculture which has been woefully underexplored by western scholars. While raising many questions relating to China's agriculture, the author has not been too successful in providing useful answers. One of the objectives of the study, according to the author, was to clarify and to explain the relationship between the modern commercial and industrial enclave sector and agriculture during 1890–1949. I do not feel that this promise has been adequately fulfilled. Nor do I see much relevance of the theories outlined in Myers' Chapter Two to understanding China's agricultural economy. Studying the agricultural problems in a framework of modern theories of economic development could probably produce a much more meaningful result.

Chao's book has three parts. Part One concerns policy and institutional changes. Part Two deals with the inputs utilization and technological changes covering problems relating to technological transformation, mechanization and improvement of farm implements, irrigation and rural electrification, fertilization, and cropping system and breeding. Part Three examines statistics of Chinese agriculture. This exercise of examining Chinese statistics can have important implications to those specializing in Chinese studies, but can be boring and confusing to other readers of the book. For this reason, the author suggests to the latter reader that this section may be treated as an appendix rather than the main text of the study.

It is obvious from Chao's study and other works on Chinese agriculture that there have been many important differences in the Soviet and Chinese agricultural policies. Among these differences the following are worthy of special note:[1]

(1) In the course of industrial development, the number of agricultural workers in China increased rather than decreased. In certain seasons of a year, there were actually evidences of labor shortage on the Chinese farm. With no apparent evidence of zero or negative marginal productivity of labor on these aspects, the Chinese experience tends to support the so-called neoclassical thesis rather than the "classical" thesis of the Lewis-Fei-Ranis type [1, 2, 3, 5, 6, 7, 8].

In the Soviet Union, on the other hand, labor has been transferred from the agricultural to the industrial sector. This transfer reflects, among other things, the high productivity of Soviet industrial labor in relation to that of the agricultural labor. The labor transfer was also made possible by the rapid mechanization of Soviet farms. Farm mechanization has progressed at a much slower pace in China than in the Soviet Union.

(2) Because of the lack of outlet for agricultural labor, China stresses primarily land-saving rather than labor-saving technological improvements for augmenting her agricultural productivity. Here the seed-fertilizer revolution has been pushed to increase agricultural productivity with a continued absorption of the expanding labor force. Unlike the Japan-Taiwan model,[2] however, this revolution has been effectuated under the system of collectivized farms rather than one of the small-scale family farms. The Soviet Union, under the pressure of labor shortage, emphasizes both labor-saving and land-augmenting improvements. Prior to the 1950's mechanization was the main thrust of Russia's agricultural revolution. Since then a greater emphasis has been placed on the seed-fertilizer technology to supplement the mechanization. In pushing the seed-fertilizer technological changes, Russia's primary interest has been in increasing the productivity of land rather than the labor absorption.

(3) As early as the 1920's, Soviet agriculture began to draw upon the industrial sector for its inputs (such as chemical fertilizers, tractors, etc.). Chinese agriculture, on the other hand, had to generate most inputs in the sector itself. Traditional agriculture relies heavily upon manual labor and uses animal waste and green manure for fertilization. This remains the prevailing mode of China's agricultural production, despite the recent government efforts to increase the use of mechanical equipment, chemical fertilizers, and other agricultural inputs produced by non-agricultural sectors.

(4) As a whole, the Soviet government appears to

[1] Some of the comments presented in this review are based on a joint study by Professor Janet Chapman and the reviewer on the comparative economic systems of China and the Soviet Union, to be published in the near future.

[2] For further discussion of the type of model, see [4].

have a greater control over its farmers than the Chinese government. This observation is based on the fact that in China the government collection has scarcely exceeded one-third of the total grain production, while the corresponding collection production ratio in the Soviet Union often amounted to more than 50 percent of the grain output. Moreover, because of the preference for labor-using techniques in China, the role of private plot has been much more important in China than in the Soviet Union. Private plot is not an institution conducive to strengthening government control.

S. H. Chou
University of Pittsburgh

References

[1] Fei, J. C. H., and G. Ranis, *Development of the Labor Surplus Economy: Theory and Policy*, Homewood, Ill., Richard D. Irwin, Inc., 1964.
[2] ———, "Agrarianism, Dualism, and Economic Development," in *The Theory and Design of Economic Development*, eds., Irma Adelman and Erik Thorbecke, Baltimore, The Johns Hopkins Press, in cooperation with the Center for Agricultural and Economic Development of Iowa State University, 1966, pp. 3–41.
[3] Johnston, B. F., "Agricultural and Structural Transformation in Developing Countries, A Survey of Research," *J. Econ. Lit.* 8:369–404, June 1970.
[4] ———, and J. Cownie, "The Seed-Fertilizer Revolution and Labor Force Absorption," *Am. Econ. Rev.* 59:569–582, Sept. 1969.
[5] Jorgenson, D. W., "The Development of a Dual Economy," *Econ. J.* 71:309–311, 1961.
[6] ———, "Testing Alternative Theories of the Development of A Dual Economy," in *The Theory and Design of Economic Development*, eds., Irma Adelman and Erik Thorbecke, Baltimore, The Johns Hopkins Press, 1966, pp. 45–66.
[7] Lewis, W. A., "Economic Development with Unlimited Supplies of Labour," *Manchester School of Economics and Social Studies*, 22:139–191, May 1954.
[8] Paglin, M., "Surplus Agriculture Labor and Development: Facts and Theories," *Am. Econ. Rev.* 55:815–832, Sept. 1965.

Dhrymes, Phoebus J., *Econometrics, Statistical Foundations and Applications*, New York, Harper and Row, 1970, xii + 592 pp. ($15.95)

Kmenta, Jan, *Elements of Econometrics*, New York, The Macmillan Company, 1971, xiii + 655 pp. ($14.95)

Theil, Henri, *Principles of Econometrics*, New York, John Wiley and Sons, Inc., 1971, xxxi + 736 pp. ($14.95)

Wonnacott, R. J., and Thomas H. Wonnacott, *Econometrics*, New York, John Wiley and Sons, Inc., 1970, ix + 445 pp. ($12.95)

Teachers and students of econometrics, long suffering under the burden of a limited number of adequate textbooks, can hardly fail to be gratified by the current population explosion in econometrics texts. If one were to place credence in the sometimes heard accusation that econometricians are faddists, one would have to infer that the present fad is writing textbooks. This not to detract from the four books listed above—each represents a superior effort and must be counted among the better econometrics texts to appear in recent years. Those who teach econometrics at more than one level will be pleased to note that, with the exception of Theil and Dhrymes, the books are not direct competitors.

Wonnacott and Wonnacott: This book is divided into two parts. Each part would make a semester's course. Part I is an elementary introduction that can be used by students with a background to elementary statistics and modicum of calculus. The authors suggest that no calculus is needed—but that's a lot to ask of students, or authors, in this day and age. On the other hand, matrix algebra and statistical theory are not required. This part introduces the student to multiple regression and such topics as serial correlation, multicollinearity, identification, and methods of estimating simultaneous equations. A good chapter on decision theory, including some Bayesian theory, concludes this section. Part II requires matrix algebra, calculus, and some vector geometry. It is structured so that chapters in Part II comprise advanced counterparts of the chapters in Part I.

Kmenta: This book is also divided into two parts. Part I does require calculus and some applied statistics. It includes chapters on statistical inference, probability distributions and sampling distributions, tests of hypotheses, and estimation. In short, it is an exposition of the statistical theory needed by econometricians. Part II covers basic econometrics beginning with simple regression and moving through multiple regression and its problems, special cases such as models with restrictions and distributed lag models, generalized least squares, and finally simultaneous equation models. Matrix algebra is used only in the last two chapters. Part I might not require a semester; Part II certainly would.

Theil: Because of Theil's international reputation, econometricians have been anxiously awaiting this book. They will not be disappointed. There is no need listing the topics—all major areas of econometrics are explored in the 686 pages of text, including a chapter entitled "Frontiers of Econometrics" that includes such topics as regression strategies and Bayesian inference. The material is as up-to-date as a text can be and by careful study a student can delve quite deeply into most any subject he chooses. This type of study has been facilitated by labelling each section A, B, and C, depending on the level of difficulty. The A sections can be read independently of the B and C sections and so on. The suggested prerequisites are elementary mathematical statistics and matrix algebra. It is true that by carefully following the A sections (and Theil outlines a suggested course), a satisfactory introductory course could be offered, but a much stronger background is required

for the B and C sections—and these sections contain some of the most interesting topics in the book. Further, the writing is terse and the notation compact, even in the introductory sections. A three or four semester course could easily be taught from this book, especially if the extensive bibliography is pursued. Finally, to demonstrate the difference between this and the two books above, the problem sections are used to extend the development of the text, rather than to provide drill.

Dhrymes: In the preface, Dhrymes states that he has written the book primarily for the graduate student in econometrics. It is an advanced book and requires advanced calculus and a good command of mathematical statistics and linear algebra. The first three chapters provide a very thorough development of statistical concepts, the next five contain an advanced development of estimating techniques for classical and simultaneous equation models, and the last four are devoted to spectral analysis, including cross-spectral analysis and applications to simultaneous equations. This book is difficult, although certainly no more so than sections of Theil's book, and each chapter is followed by an extensive reference list.

General Comments: For a course taught to seniors or beginning graduate students with limited backgrounds, Wonnacott and Wonnacott is my choice. The text is well written and the graphs and problems are excellent. In Part II, matrix equations are depicted in charts, using rectangles of appropriate size and, as a result, the explanations of some rather messy equations (three-stage least squares on page 389, for example) are superb. This book would be good for individual study—in the event you feel a little rusty. The authors suggest Part II will prepare students for texts like that of E. Malinvaud [2]. I don't believe it goes quite that far, but it should be an excellent preparation for intermediate books.

For a course in applied econometrics taught exclusively to graduate students with some training in calculus and descriptive statistics, my choice would be Kmenta, although a good case could be made for Part II of Wonnacott and Wonnacott. Kmenta's Chapter 6 on estimation is good and his Chapters 7 though 11 contain the most complete treatment of single equation models without using matrix algebra that I have seen. Kmenta is reputedly an excellent teacher and his explanations certainly bear that out. He presents intuitive insights that can only come to one experienced in the classroom. An example I particularly like is his comparison of parameter estimation to target shooting (pp. 13 and 168). The level of mathematical maturity increases rapidly in Chapters 12 and 13, which require matrix algebra. I would have preferred to see Professor Kmenta omit much of the material in Chapters 2 to 5, which is largely elementary statistics, and use that space to expand and develop more gradually the subject matter of Chapters 12 and 13.

For an advanced course taught for econometric majors or students with substantial mathematics backgrounds, Theil would be my choice—unless, of course, one wanted to discuss spectral analysis as contained in Dhrymes, one of the few subjects Theil does not cover. In my opinion, Theil's book promises to become the standard text for advanced courses.

The books all have some shortcomings; some perhaps could have been avoided and some perhaps reflect the present state of econometrics. First, the books are primarily "statistical" econometrics rather than "economics" econometrics. Problems of statistical methods, interpretations, and pitfalls are emphasized to the near exclusion of similar problems with the economic models. This shortcoming was much more forgiveable in earlier books, when many of the statistical methods of econometrics could be found only in the journals. Students do need to know how to specify and interpret econometric models, which often differ from the standard models described in economic theory courses. (A good example of this is Malinvaud's discussion of the Keynesian consumption function, [2, ch. 4].) Carl Christ's book [1] remains the only econometrics text around that discusses economic models.

All econometric theory is meant to guide applications, so it would not be fair to say these books neglect applied aspects of econometrics. It can be argued that no two applied problems are alike and therefore all applied workers should be versed in theory. Still, none of these books presents a concrete example of how to attack a set of numbers so as to unlock the information (if any) contained therein. Take deflating, for a particularly horrible example. Deflating probably causes more troubles than it cures; yet, it is not discussed systematically in any of these books. Dhrymes (p. 51) throws out an interesting tidbit when discussing a paper by Fred Waugh: "The consumption data are per capita and the price data are "deflated" by per capita income—a dubious procedure at best." But he does not pursue the issue.

It seems redundant to suggest that another econometrics text is needed. Yet a book that discusses econometric models, their uses, methods of estimation, and shortcomings from an applied point of view would be useful. While some might argue that such a book would increase the dangers of misapplications, I believe it would more likely reduce such errors—errors that now occur because the gap between the applied worker and the theoretical worker is so wide in econometrics. We need someone to do for econometrics what Professor George Snedecor did for statistical methods in the agricultural and biological sciences.

John P. Doll
University of Missouri-Columbia

References

[1] Christ, Carl, *Economic Models and Methods*, New York, John Wiley & Sons, Inc., 1966.

[2] Malinvaud, E., *Statistical Methods of Econometrics*, Chicago, Rand McNally and Company, 1966.

Intriligator, Michael D., *Mathematical Optimization and Economic Theory*, Englewood Cliffs, Prentice-Hall, Inc., 1971, xix + 508 pp. ($13.95)

Since the now classical publication of R. G. D. Allen's outstanding book on mathematical analysis for economists [1], the scope and contents of mathematical economics textbooks have gone through changes. Drastic changes took place in 1958 along with the appearance of the Dorfman-Samuelson-Solow volume [3], which was followed by a series of outstanding books by mathematical perfectionists such as Debreu [2], Gale [4], and Nikaido [6]. The developments in this direction must have left many instructors perplexed, tantalized, bewildered, and/or confused in teaching economic theory, even at the freshman level. Lancaster's 1968 volume [5] did not make this situation any easier.

Intriligator takes a determined approach in this book and sets out with a very careful presentation of mathematical optimization techniques in developing both static and dynamic economic theories. This usually makes this type of textbook rather heavy at the beginning and thus may scare many students away. On the contrary, this book is deceptively and surprisingly easy to read. It consists of five parts and two appendices, Part I being just a short introduction.

Part II is devoted to static optimization and handles such topics as mathematical programming problems, classical and non-linear programming approaches, linear programming, and game theory. Throughout this rather difficult part, Intriligator's presentations are clear, effective, and even almost tangible (through many well-prepared diagrams). The use of vectors and matrices consistently from the beginning is a daring and commendable device.

Part III is made up of four application chapters: theory of household, theory of the firm, general equilibrium, and welfare economics. It comes as a surprise that this part actually covers, in a neat and compact way, most of the topics (or even more) in most widely used intermediate microeconomic theory textbooks.

Part IV is challenging, containing such topics as calculus of variation, dynamic programming, and maximum principle—now standard techniques in optimal control theory dealing with dynamic economic problems—and differential games, a newly developed and still developing field. To convince oneself how powerful these techniques are, one can easily find some esthetically beautiful dynamic economic models such as the neoclassical growth model, an optimal growth model, the Uzawa two sector growth model, and a heterogeneous capital good model á la Samuelson-Solow in Part V.

The two appendices are for (1) analysis dealing with fundamental concepts on sets, relations and functions, metric and vector spaces, convex sets and functions, and differential calculus, and (2) matrices dealing with matrix definitions and operations, linear transformations, inverses, characteristic roots and vectors, quadratic forms, and matrix derivatives.

At the end of each chapter are a number of exercise problems and footnotes that will enrich the understanding of topics and tools developed in the chapter. The bibliography following the footnotes is well documented.

The chapter on general equilibrium, Chapter 9, is enjoyable, and Intriligator shows a very good command of the topic. However, a few confusions took place on page 234 where (9.2.33) should read as

$$\{x \mid Bx \leqq r, x \geqq 0\},$$

and (9.2.34) should be defined as

$$P = \{p \mid \lambda x^0 \text{ maximizes } p(I - A)x \text{ subject to } Bx \leqq r^0, x \geqq 0 \text{ and } p \in S^n\},$$

where

$$S^n \text{ is an } n\text{-simplex;}$$

or, more explicitly,

$$P = \left\{ p \;\middle|\; \max p\delta B \text{ subject to } p \in S^n, \text{ and } \delta = \begin{pmatrix} \delta_1 \\ \cdot \\ \cdot \\ \delta_m \end{pmatrix}, \right.$$

where

$$\left. \delta_i \geqq 0 \text{ for } B_i x = r_i^0 \text{ and } \delta_j = 0 \text{ for } B_j x < r_j^0 \text{ and } \sum_j \delta_j = 1 \right\}.$$

The price adjustment function Δ defined in (9.3.11) is too naive to satisfy the continuity assumption of the mapping from P to $\bar{P}$.

In Chapter 10, under Section 10.3, Market Failure, extremely interesting and important problems of externalities and public goods are given only a page of passing remarks. However, a conscientious instructor may feel a great urge to add a number of contemporary issues, such as pollution problems, to make welfare economics a more positive topic and discipline in economics.

This book is a great accomplishment as a textbook by an outstanding instructor and researcher in his field. It is a challenge to teach a course using this as the textbook without losing touch with real world economic issues. In the field of agricultural economics, there are many example problems to supplement the text even in economic dynamics. This book will prove to be very useful to bridge a gap between applied economic professions and those in the theoretical field.

T. TAKAYAMA
University of Illinois

References

[1] ALLEN, R. G. D., *Mathematical Analysis for Economists*, London, Macmillan and Co., Ltd., 1938.
[2] DEBREU, GERALD, *Theory of Value*, New York, John Wiley & Sons, Inc., 1959.
[3] DORFMAN, ROBERT, PAUL A. SAMUELSON, AND ROBERT M. SOLOW, *Linear Programming and Economic Analysis*, New York, McGraw-Hill Book Company, Inc., 1958.

[4] Gale, David, *The Theory of Linear Economic Models*, New York, McGraw-Hill Book Company, Inc., 1960.
[5] Lancaster, Kelvin, *Mathematical Economics*, New York, The Macmillan Company, 1968.
[6] Nikaido, Hukukane, *Convex Structures and Economic Theory*, New York, Academic Press, Inc., 1968.

Nelson, Richard R., T. Paul Schultz, and Robert L. Sleighton, *Structural Changes in a Developing Economy: Colombia's Problems and Prospects*, Princeton, Princeton University Press, 1971, xii + 322 pp. ($12.50)

This book draws together a group of studies sponsored by the Agency for International Development and carried out by the Rand Corporation in Colombia from 1966 to 1969. Like many publications on development it covers less territory than suggested by the title. It includes very little on agriculture or the rural sector. Nevertheless, if one is interested in population theory, industrial growth, and/or economic policy making in Colombia during the past two decades the book is well worth reading.

Readers of this *Journal* will probably find the first part of the book most interesting. Here Schultz presents his family planning hypothesis which posits a relationship between the economic environment faced by parents and the number of children they choose to have. His analysis takes Malthus head on and appears to break new ground toward the construction of a theory of population growth. Census data from Colombia, Puerto Rico, and Taiwan are utilized to test his hypothesis. He finds that births appear to be limited under any of the following conditions: where women participate with great frequency in the commercial labor force, where significant schooling is available for children, where adult educational levels are substantial, and where infant mortality rates have been reduced. His analysis suggests that general economic growth supplements family planning efforts in sharply reducing population growth rates. Recent declines in birth rates in several rapidly developing countries appear to bear out this conclusion.

Schultz also presents an analysis of rural-to-urban migration in Colombia between 1951 and 1964. His theory and conclusions here are more conventional. Using census data for these two years he attempts to determine the causes of internal migration and characteristics of migrants. He concludes that there has been a large rural-to-urban movement during the period studied, that income differentials were important in explaining movement, and that migration was selective with respect to age, education, and sex.

Much of the complexity of migration processes is masked in aggregate census data. The 1951 Population Census of Colombia, however, has unique limitations which Schultz does not adequately clarify. The year 1951 was one of the hot periods in a virtual civil war which ebbed and flowed between 1948 and the late 1950's in Colombia. A number of areas could not be safely entered by enumerators. Other areas were only partially enumerated from the safety of an urban center. How this affects Schultz's migration data is not made clear.

The second and largest portion of the book presents an analysis of manufacturing development in Colombia during the 1950's and 1960's. Attention focuses on the dualistic nature of the manufacturing sector, factors which led to a slowdown in industrial growth during the 1960's, and policies which might help to accelerate again growth of modern manufacturing. The authors suggest that Colombia's manufacturing sector is made up of two subsectors: a modern portion which relies heavily on imports, skilled labor, foreign technology, and monopoly pricing, and a craft sector which lacks these characteristics. They go on to argue that growth in the modern sector is retarded by the foreign exchange constraint and lack of competition. Monopoly powers in the modern sector hold prices up, restrict the number of employees, and cause an increase in the wages paid by the modern versus the craft manufacturers.

The third and last portion of the book presents a discussion of Colombia's foreign exchange policy and also outlines a number of issues for future policy consideration. Particular emphasis is placed on the political forces which have caused a consistent underpricing of foreign exchange. The authors argue that this is due to a complex set of trade-offs among special interest groups. In these trade-offs growth considerations are usually secondary. It is also argued that the major rationale for this policy has been the feeling that devaluation causes inflation, which in turn is associated with a further distortion in the distribution of income between the modern and craft manufacturing subsectors. The authors challenge this rationale and thereby provide the central thread which ties the three parts of this book together. They argue that a liberalized foreign exchange and trade policy would result in less inflationary pressure. Allowing market forces more sway in the modern manufacturing subsector would better ration foreign exchange, increase competition, increase efficiency, expand manufacturing employment, encourage exports, and accelerate overall growth. They feel that wage differences between the modern and craft manufacturing workers would also be reduced rather than increased by this approach. Overall, the increased economic activity would provide more employment for the rural-to-urban migrants, and the improved economic environment would help to dampen population growth.

I generally agree with the authors' recommendations on foreign exchange policy. I feel, however, that they might have explored an alternative explanation for the lack of growth in Colombia's modern manufacturing during the 1960's: that modern industrial growth in Colombia is sharply limited by the thin domestic markets available for most manufactured goods. Much of Colombia's industrial base is used far below capacity. I would argue that adjustments in trade, monetary, and fiscal policies can only have at best a partial impact on these conditions. With Colombia's highly skewed distribution of property ownership and access to income streams, well over half of its 25 million people, mainly the rural poor, are not wired into the market for manufac-

tured goods. With little chance of dramatically increasing manufactured exports, Colombia must look to sharp increases in effective domestic demand to spur industrial growth. This can only come about through rapid agricultural growth which spreads benefits fairly equitably among a large number of rural poor.

In sum, the authors do an excellent job on the topics which they treat. They focus almost exclusively, however, on urban, industrial, and aggregate issues. Those interested in agriculture, the rural area, and overall development policy in Colombia will do little more than whet their appetites on this book.

DALE W ADAMS
The Ohio State University

Steiner, Gilbert Y., *The State of Welfare*, Washington, D.C., The Brookings Institution, 1971, + 346 pp, ($7.50)

Conservatives think there is too much of it and that it is inequitable to boot. Liberals likewise believe it to be inequitable—for different reasons—but argue there is too little of it. All agree that its state is crisis and chaos. It should come as no surprise, then, to learn that Gilbert Steiner's *The State of Welfare* indicts the welfare system in the U.S. To do otherwise is inconceivable. It is more, however, for it provides political histories of four of the system's major components—Aid to Families with Dependent Children (AFDC), Public Housing, the Food Stamp Program (FSP), and Veterans Relief—along with the development of Nixon's Family Assistance Program (now built into H.R #1) as well as his ideas of the "Substance and Strategy of Reform." It also chronicles recent efforts to forge political pressure groups out of welfare recipients. Given the avalanche of words published each year, a judgment that it is "must reading for all economists" would be utter nonsense. However, it is highly recommended to agricultural economists as a lucid and concise summary of the history, politics, and possible short-run future of the nation's welfare system.

Steiner's analysis is neither radical nor conservative, lying well within the bounds of the liberal tradition. (How could it be otherwise since he is Director of Governmental Studies at Brookings?) The actors his analyses bring to center stage are the usual collection of pressure groups, Congressional committee chairmen, Presidents, and administrators of federal agencies. Congressional hearings and reports, governmental studies, and Administration releases bulk large among his resource material. His prescriptions are characterized by that slight cynicism common to watchers of the Washington scene, yet they do in places contain some lingering altruism and naiveté. The latter may simply be his "druthers" unwatered by political feasibility.

Steiner sees the thrashing around that occurred in the AFDC program during the Sixties as ". . . a probable prerequisite to innovation." Perhaps. Certainly the social service approach did not improve the social adjustments of the recipients; the attempt to shift more of the costs to the states was bound to fail; the move to put mothers to work with work training and child day care facilities did not and could not move many into the labor force; and, the reorganization of the W in HEW did not bear immediate fruit. Steiner's analysis of the political forces behind these various attempts is deft. But I was disappointed that he did not weigh the evidence and apportion the blame with respect to the toughest and most important question: to what extent were faulty program design, bad administration, and lack of funds the factors that brought the efforts of the Sixties and the program down around our ears? If most of the blame must go to lack of funds, then the proposed cash benefit approach must be much more efficient if it is to succeed.

The analysis of the political forces leading up to the Nixon Administration's position on welfare (the Family Assistance Program) is comprehensive. It clearly indicates that social welfare professionals have given way to economists as the source of ideas and program proposals. Given the experience of the Sixties, one can only wish "us" luck. The analysis is deficient in that it stops before the Senate Finance and House Ways and Means Committees moved actively on the Family Assistance Program (FAP). But an author must stop somewhere and the FAP is not a bad stopping place.

Public housing is treated in two long chapters, while one chapter is devoted to the Food Stamp Program (FSP). Anyone who has followed the Food Stamp Program and the politics of hunger will find little that is new in his treatment of this subject.

The chapter on Veterans Relief details the roles played by the various veterans associations and the House Veterans Affairs Committee in formulating and maintaining veterans relief programs separate from and superior to the programs available to others. To one conversant with the politics of agriculture, the plot is the same but different actors play the parts.

The chapter dealing with the recent history of attempts to forge political pressure groups out of the poor analyzes the success of the National Welfare Rights Organization and the failure of the Poor Peoples' Campaign. The former's success is attributed to its attention to one narrow issue—higher benefit levels of welfare recipients—and to its tactic of pursuing this issue at the point in the system at which the organization has power, the local level. The failure of the latter is attributed to its attempt to concern itself with too many issues and to pursue them where it had no strength—at the federal level.

Steiner's final chapter is entitled "The Substance and Strategy of Reform." His recommendations for reform are not unusual: extension of programs to all the poor, elimination of interstate variations in benefit levels, raised benefit levels, and the dismantling of in-kind welfare programs along with Veterans Relief. His arguments over strategy are more interesting. In contrast to many other analysts, he argues that neither the departmental nor the Congressional committee jurisdiction is especially important; welfare reform can be achieved without moving pro-

grams from one department to another or from one Congressional committee to another. More relevant, he argues, is whether there are clear signals from the White House as to preferred policies and programs, federalization of the financing of welfare programs, and a longer but not indefinite authorization of program expenditures. Finally, he argues the necessity of a group to champion welfare client interests. This group can either be a competitive Congressional committee or a political pressure group. This last appears to the reviewer to be most important.

The State of Welfare is a good treatment of the political economy of welfare with emphasis on the politics. It will be of interest to the economist who wishes to educate himself in the area. And it would be a useful addition to the reading lists of agricultural and rural policy courses at either the undergraduate or graduate levels.

W. Keith Bryant
University of Minnesota

Wollman, Nathaniel, and Gilbert W. Bonem, *The Outlook for Water: Quality, Quantity, and National Growth,* Baltimore, The Johns Hopkins Press, 1971, xviii + 286 pp. $12.00

Wollman's pioneering work [1] in providing projections of regional water supply and requirements for the nation is familiar to most engineers and water policy specialists, although it has received less attention from economists. It has been a major stimulus to further work in this important area within the federal government. Now, Wollman and Gilbert Bonem have given us a revised and amplified version which will be more accessible to economists and others outside of government.

The *Outlook for Water* cannot be recommended for the bedside reading shelf. It is a massive presentation of information, most of it quantitative and in tabular form. To read it lightly is impossible and to read it seriously makes heavy demands upon the reader's background in water resource technology (for understanding) and economics (for critical appraisal). Most readers will be grateful for the initial 37-page summary and will use selectively the more detailed account which follows. Other researchers will be particularly grateful for the data-packed appendices which comprise nearly half of the volume.

Those interested in new economic theory must look elsewhere. Some will even object that the authors have neglected to use the simple and fundamental notion of the demand curve in adopting the requirements approach which has provoked so much economic criticism in previous incarnations. Yet the authors are not to be accused of economic naiveté; they go to great lengths in pointing out the limitations of their many assumptions and the qualifications which must be attached to their conclusions. They have struggled with a problem characterized by many conceptual difficulties and even more numerous and serious data deficiencies. Few indeed are their fellow economists who would not shrink from undertaking an assignment of this difficulty, and one which cannot help but leave them exposed to criticism at many points.

Wollman and Bonem basically explore the trade-off between waste treatment and low flow augmentation as means of meeting expanding water requirements. They assume continued population and economic growth, no change in technology, and a water quality objective of 4 mg/l. of dissolved oxygen. (Alternative rates of population growth and levels of D.O. are also examined.) The stochastic nature of the hydrologic conditions underlying supply projections is recognized through the adoption of a 98 percent reliability criterion. (Alternative criteria of 90 percent and 95 percent are also tested.)

Three major conclusions emerge from this analysis. First, given the authors' assumptions, high quality water and continued rapid growth will become incompatible national objectives early in the next century. Second, quantitative shortages of water will become increasingly acute in the Southwest, barring large-scale interregional water transfers or technological breakthroughs in water supply. Third, on the national scene water quality problems will soon become much more important than quantitative shortages. This reviewer is inclined to add a fourth conclusion which stands out in the analysis: that water storage for low flow augmentation is at best a temporary and very expensive solution to intensifying water quality problems.

Wollman and Bonem identify several policy issues which flow from their work. First, this study raises once again what may be the central question for our time, namely, whether continued high rates of growth are desirable. Second, it points up the trade-offs between continued reservoir construction and the benefits of naturally flowing rivers. Third, it underscores the strong bias towards further reservoir construction which is a consequence of the cost-sharing rules for federal water resource programs. Fourth, it poses the question of what level of risk in meeting water supply requirements the public will accept and what costs would be incurred in reducing the risk level. Fifth, it brings into sharp focus the social choice between levels of water quality and the costs implicit in attaining them.

In conclusion, this is not a book for everyone to read, but it is a book with implications for everyone. It will become a major reference and stimulus for future research in an area of major importance. Surely every resource economist will want to be familiar with it. Much additional research is required to further the analysis of the nation's supply and demand for water and to illuminate the policy choices available. Wollman and Bonem have made an impressive start.

William B. Lord
The University of Wisconsin

Reference

[1] Wollman, Nathaniel, *Water Supply and Demand,* Committee Print No. 32, Senate Select Committee on National Water Resources, 86th Cong., 2nd sess., 1960.

Books Received

Agarwal, S. K., *Economics of Land Consolidation in India,* New Delhi, S. Chand & Co. (Pvt.) Ltd., 1971, xii + 159 pp. Rs. 20.00.

Arbuckle, W. S., *Ice Cream,* 2nd ed., Westport, The AVI Publishing Company, Inc., 1972, vii + 474 pp. $19.00.

Barkley, Paul W., and David W. Seckler, *Economic Growth and Environmental Decay: The Solution Becomes the Problem,* New York, Harcourt Brace Jovanovich, Inc., 1972, vii + 193 pp. $2.95. Paper.

Berger, Samuel R., *Dollar Harvest,* Lexington, D. C. Heath and Company, 1971, xi + 221 pp. $7.95.

Boulding, Kenneth E., Elvis J. Stahr, Solomon Fabricant, and Martin R. Gainsbrugh, *Economics of Pollution,* New York, New York University Press, 1971, 158 pp. Price unknown.

Cancian, Frank, *Change and Uncertainty in a Peasant Economy: The Maya Corn Farmers of Zinacanton,* Stanford, Stanford University Press, 1972, xiv + 208 pp. $7.95.

Clepper, Henry, *Professional Forestry in the United States,* Baltimore, The Johns Hopkins Press for Resources for the Future, 1971, ix + 337 pp. $10.00.

Cooper, Charles A., and Sidney S. Alexander, eds., *Economic Development and Population Growth in the Middle East,* New York, American Elsevier Publishing Company, Inc., 1972, xviii + 620 pp. $19.95.

Cowling, Keith, David Metcalf, and A. J. Rayner, *Resource Structure of Agriculture: An Economic Analysis,* New York, Pergamon Press Ltd., 1970, xiii + 248 pp. $7.40.

Dantwala, M. L., and C. H. Shah, *Evaluation of Land Reforms,* Vol. 1, New Delhi, Arcee Press for the U.S. Agency for International Development, 1971, v + 197 pp. Rs. 15/-.

De Benedictis, M. L. de Angelis, and G. Balestrieri, *Il Bilancio Programmato,* Milano, Franco Angeli Editore, 1971, 136 pp. 3.800 Lire.

Deman, J. M., and P. Melnychyn, eds., *Symposium: Phosphates in Food Processing,* Westport, The AVI Publishing Company, Inc., 1971, ix + 242 pp. $20.00.

Drilon, J. D., Jr., *Agribusiness Management Resource Materials, Volume 1, Introduction to Agribusiness Management,* Tokyo, Asian Productivity Organization, 1971, 236 pp. Price unknown. Paper.

Edmond, J. B., and G. R. Ammerman, *Sweet Potatoes: Production, Processing, Marketing,* Westport, AVI Publishing Company, Inc., 1971, iv + 334 pp. $24.00.

Erickson, Erling A., *Banking in Frontier Iowa, 1836–1865,* Ames, The Iowa State University Press, 1971, x + 183 pp. $7.50.

Falcon, Walter P., and Gustav F. Papanek, eds., *Development Policy II: The Pakistan Experience,* Cambridge, Harvard University Press, 1971, xiii + 267 pp. $9.00.

Ferris, John, Timothy Josling, Brian Davey, Paul Weightman, Denis Luvcey, Liam O'Callaghan, and Vernon Sorenson, *The Impact on U.S. Agricultural Trade of the Accession of the United Kingdom, Ireland, Denmark and Norway to the European Economic Community,* East Lansing, Michigan State University, Institute of International Agriculture, 1971, xiii + 367 pp. $3.00. Paper.

Fishel, Walter L., ed., *Resource Allocation in Agricultural Research,* Minneapolis, University of Minnesota Press, 1971, ix + 391 pp. $14.00.

Fox, Irving K., ed., *Water Resources Law and Policy in the Soviet Union,* Madison, The University of Wisconsin Press, 1971, viii + 256 pp. $8.50.

Fried, Jerome J., and Milton C. Edlund, *Desalting Technology for Middle Eastern Agriculture,* New York, Praeger Publishers, Inc., 1971, xv + 113 pp. $12.50.

Friedland, William H., and Dorothy Nelkin, *Migrant Agricultural Workers In America's Northeast,* New York, Holt, Rinehart and Winston, 1971, xix + 281 pp. Price unknown. Paper.

Frome, Michael, *The Forest Service,* New York, Praeger Publishers, 1971, xiii + 241 pp. $8.75.

Geer, Thomas, *An Oligopoly: The World Coffee Economy and Stabilization Schemes,* New York, The Dunellen Publishing Company, Inc., 1971, xi + 323 pp. $10.00.

Greig, W. Smith, *The Economics of Food Processing,* Westport, The AVI Publishing Company, Inc., 1971, xi + 373 pp. $21.00.

Griliches, Z., and V. Ringstad, *Economies of Scale and the Form of the Production Function: An Econometric Study of Norwegian Manufacturing Establishment Data,* Amsterdam, North-Holland Publishing Company, 1971, ix + 204 pp. $12.00.

Haring, Joseph E., *Urban and Regional Economics: Perspectives for Public Action,* Boston, Houghton

Mifflin Company, 1972, viii + 307 pp. $4.95. Paper.

Hastings, James R., and Raymond M. Turner, *The Changing Mile: An Ecological Study of Vegetation Change With Time in the Lower Mile of an Arid and Semiarid Region,* Tucson, The University of Arizona Press, 1965, xi + 317 pp. $12.50.

Hieronymus, Thomas A., *Economics of Futures Trading: For Commercial and Personal Profit,* New York, Commodity Research Bureau, Inc., 1971, xiii + 338 pp. $12.95.

Holloway, Robert J., Robert A. Mittelstaedt, and M. Venkatesan, eds., *Consumer Behavior: Contemporary Research in Action,* Boston, Houghton Mifflin Company, 1971, xii + 458 pp. Price unknown. Paper.

Holmes, A. Stewart, *Market Structure, Conduct, and Foodgrain Pricing Efficiency: An Indian Case Study,* New York, MSS Educational Publishing Company, Inc., 1971, 123 pp. Price unknown. Paper.

Hunt, K. E., ed., *Policies, Planning and Management for Agricultural Development,* Papers and Reports of the Fourteenth Internation Conference of Agricultural Economists: Minsk, U.S.S.R., 1970, Oxford, Institute of Agrarian Affairs for International Association of Agricultural Economists, 1971, xiv + 632 pp. £5.

Johnson, Walter L., and David R. Kamerschen, eds., *Readings in Economic Development,* Cincinnati, South-Western Publishing Co., 1972, vii + 515 pp. Price unknown. Paper.

Kilby, Peter, ed., *Entrepreneurship and Economic Development,* New York, The Free Press, 1971, viii + 384 pp. Price unknown.

Kmenta, Jan, *Elements of Econometrics,* New York, The Macmillan Company, 1971, xiii + 655 pp. Price unknown.

Kuo, Leslie T. C., *The Technical Transformation of Agriculture in Communist China,* New York, Praeger Publishers, 1972, xx + 266 pp. $16.50.

Lee, Teng-hui, *Intersectoral Capital Flows in the Economic Development of Taiwan, 1895–1960,* Ithaca, Cornell University Press, xx + 197 pp. Price unknown.

Margen, Sheldon, ed., *Progress in Human Nutrition,* Westport, The AVI Publishing Company, Inc., 1971, xi + 228 pp. $15.00.

Padberg, Daniel L., *Today's Food Broker: Vital Link in the Distribution Cycle,* New York, Chain Store Publishing Corporation, 1971, xii + 200 pp. $10.00.

Pattanaik, Prasanta K., *Voting and Collective Choice: Some Aspects of the Theory of Group Decision-Making,* New York, Cambridge University Press, 1971, viii + 184 pp. $10.00.

Pederson, Carl S., *Microbiology of Food Fermentations,* Westport, The AVI Publishing Company, Inc., 1971, vii + 283 pp. Price unknown.

Pomeranz, Yeshajahu, and J. A. Shellenberger, *Bread Science and Technology,* Westport, The AVI Publishing Company, Inc., 1971, ix + 262 pp. $17.00.

Ross, John B., *The Economic System of Mexico,* Stanford, California Institute of International Studies, 1971, xv + 131 pp. $5.00.

Rothblatt, Donald N., *Regional Planning: The Appalachian Experience,* Lexington, D. C. Heath and Company, 1971, xvii + 281 pp. Price unknown.

Ruthenberg, Hans, *Farming Systems in the Tropics,* New York, Oxford University Press, 1971, xv + 313 pp. $17.75.

Scherer, F. M., *Industrial Market Structure and Economic Performance,* Chicago, Rand McNally & Company, 1970, xi + 376 pp. Price unknown.

Schlotter, H. G., ed., *Die Willensbildung in der Agrarpolitik,* Munich, BLV Verlagsgesellschaft, 1971, viii + 455 pp. DM 70.00.

Schmutz, Ervin M., Barry N. Freeman, and Raymond E. Reed, *Livestock-Poisoning Plants of Arizona,* Tucson, The University of Arizona Press, 1968, 176 pp. $6.00.

Solow, Barbara Lewis, *The Land Question and the Irish Economy, 1870–1903,* Cambridge, Harvard University Press, 1971, ix + 247 pp., $8.50.

Somers, G. G., and W. D. Wood, eds., *Cost-Benefit Analysis of Manpower Policies: Proceedings of a North American Conference,* Kingston, Industrial Relations Centre, Queen's University, 1969, xx + 272 pp. $5.00. Paper.

Steele, Howard L., Francisco Vera Filho, and Robert S. Welsh, *Comercialização Agricola,* São Paulo, Editora Atlas S. A., 1971, 443 pp. Price unknown. Paper.

Streets, Robert Burley, Sr., *Diseases of the Cultivated Plants of the Southwest,* Tucson, University of Arizona Press, 1969, xvii + 390 pp. $9.50.

Announcements

ANNUAL MEETING
AMERICAN AGRICULTURAL ECONOMICS ASSOCIATION

University of Florida
Gainesville, Florida
August 20–23, 1972

Format of the 1972 Annual Program

General Topic Areas for Seminars at Annual Meeting

MONDAY MORNING, AUGUST 21

Presidential Address: "The Quality of Economics," Emery Castle, Oregon State University

Invited Address: "Southern Tradition and Regional Progress: A Perspective from the 1970's," William H. Nichols, Vanderbilt University

MONDAY AFTERNOON, AUGUST 21

Seminar Session 1.0: Agricultural Productivity and Environmental Quality

Chairman: Max Langham, University of Florida

Paper: J. Charles Headley, University of Missouri

Seminar Session 2.0: Community Development in the 1970's

Chairman: John Dunbar, Purdue University

Paper: R. J. Hildreth and W. Neill Schaller, The Farm Foundation

Sectional Meeting A: Agribusiness Research

Chairman: William A. Cromarty, Connell and Company, Inc.

Paper: "Statistical vs. Judgment and Audience Considerations in the Formulation and Use of Econometric Models," Richard T. Crowder, Wilson and Company

Paper: "Combining Statistical Techniques with Economic Theory for Commodity Forecasting," Walter F. Myers, Connell and Company

Paper: "Allocation of Random Supply of Tomatoes of Varied Quality Produced in Different Areas Among Plants Producing Multiple Product Lines," Harvey S. Kuang, Hunt-Wesson Foods

Paper: "An Industrial Perspective on Agricultural Policy in the 1970's," William Sparks, Cook Industries

Sectional Meeting B: Applied Welfare Economics

Chairman: David Seckler, Colorado State University

Paper: "Welfare Indicators in Utility Theory: Measurement and Use in Development Programs," Jurg Bieri, Alain de Janvry, and Andrew Schmitz, University of California (Berkeley)

Paper: "Welfare Analysis of Poverty Programs," Lee Bawden, University of Wisconsin

Sectional Meeting C: Commodity Trade in the 1970's

Chairman: Kenneth Ogren, U.S. Department of Agriculture

Paper: "The General Environment for Agricultural Trade," Gary Seevers, Council of Economic Advisors and Oregon State University

Paper: "The Outlook for U.S. Agricultural Exports," Quentin M. West, ERS, USDA

MONDAY EVENING, AUGUST 21

Industry Dinner

International Dinner

TUESDAY MORNING, AUGUST 22

Annual Business Meeting

General Session: Education and Development

Chairman: Gerald Leslie, University of Florida

Paper: "Economics of the Value of Time of Rural People," T. W. Schultz, University of Chicago

Paper: "The Economic and Social Consequences of Education," William Sewell, University of Wisconsin

TUESDAY AFTERNOON, AUGUST 22

Seminar Session 3.0: Our Obsolete Data Systems

Chairman: Dean E. McKee, Deere & Company

Paper: "New Directions and Opportunities," James T. Bonnen, Michigan State University

Seminar Session 4.0: The Government and Forest Resource Management

Chairman: William Leuschner, Virginia Polytechnic Institute

Paper: "Public Pressures and Values, Federal Policy Changes and Future Timber Supply," James G. Yoho, International Paper Company

Seminar Session 5.0: Institutional Economics

Chairman: Stephen Smith, University of Wisconsin

Paper: "Toward an Analytical Institutional Economics," Al Schmid, Michigan State University

Sectional Meeting D: Analytical Methods in Agricultural Economics

Chairman: John P. Doll, University of Missouri
Paper: "Estimation," George Judge, University of Illinois
Paper: "Optimization," Richard H. Day, University of Wisconsin
Paper: "Simulation," Stanley R. Johnson and Gordon Rausser, University of California
Sectional Meeting E: Continuing Education in the 1970's
Chairman: Kenneth Farrell, U. S. Department of Agriculture
Paper: "Research Support for Continuing Education"
Paper: "Delivery Systems for Continuing Education"
Paper: "The Clientele for Continuing Education in the 1970's," B. F. Stanton, Cornell University

TUESDAY EVENING, AUGUST 22

Fellows Address
Paper: Earl O. Heady, Iowa State University
Awards Program
Chairman: Chester B. Baker, University of Illinois

WEDNESDAY MORNING, AUGUST 23

(The Wednesday morning general session is held in conjunction with the Workshop on the Improvement of Education in Agricultural Economics by Defining Goals, Developing Curricula, and Improving Instruction. The workshop will continue through Friday morning.)

General Session: Changing Goals for Higher Education
Chairman: James Nielson, Washington State University
Paper: "The Changing Goals of Higher Education," Charles E. Bishop, University of Maryland
Paper: "Higher Education in the Rural Social Sciences," Arthur T. Mosher, Agricultural Development Council
Sectional Meeting F: The Market for Economists in the 1970's
Chairman: Lester V. Manderscheid, Michigan State University
Paper: "The Market for Economists," Francis M. Boddy, University of Minnesota
Paper: "The Market for Agricultural Economists," John D. Helmberger, University of Minnesota
Sectional Meeting G:
Chairman: Fred Abel, Environmental Protection Agency
Paper: "The Case for Zero Growth," Herman Daley, Louisiana State University
Paper: "Implications of Zero Growth for Agricultural Commodity Demand," William J. Serow, University of Virginia
Paper: "Implications of Zero Growth for the Spatial Distribution of Economic Activity," George Brinkman, Kansas State University

WEDNESDAY AFTERNOON, AUGUST 23
(Education Workshop Continues)

Goals of the Workshop, James Nielson, Director of Research Washington State University
Curriculum Development
Chairman: Fred Mangum, North Carolina State University
1st paper, "Curriculum Development: Principles and Methods," Russell Kropp, Florida State University
2nd paper, "Guidelines for Curriculum Changes in Agricultural Economics," Lester V. Manderscheid, professor of agricultural economics, Michigan State University

Some Curricular Models (four, 15 minutes each and 15 minutes for discussion)

THURSDAY MORNING, AUGUST 24

Roundtable Discussion (four running concurrently)

Each Roundtable will have a chairman to lead discussion and prepare a report for the Friday Workshop session. Each chairman should select a recorder to assist him. Each resource person will be given 10 minutes to state his views, leaving 50 minutes for discussion. We expect to have 15–20 participants at each workshop.

Roundtable A. Preparation of Students for Careers in Business
Chairman: A. C. Hoffman, Kraft Foods, Chicago (ret.)
Roundtable B. Preparation of Students for Careers in Extension and Other Public Service
Chairman: James Nielson, Director of Research, Washington State University
Roundtable C. Preparation of Students for Careers in Research
Chairman: John McNeely, Texas A&M University
Roundtable D. Preparation of Students for Careers in Teaching
Chairman: Fred Mangum, North Carolina State University

THURSDAY AFTERNOON, AUGUST 24

Teaching Development
Teaching Methods
Evaluation of Teaching and Rewards

FRIDAY MORNING, AUGUST 25

Roundtable meetings for finalizing reports to the Workshop
Reports from the Roundtable groups
Summary and Evaluation of the Workshop

Contributed Papers Sessions of the AAEA Annual Meeting

Contributed papers sessions will be organized as subsections within the subject matter areas of the

seminar sessions and several of the sectional meetings. There will be no limit placed on the number of contributed papers sessions. Contributed papers sessions will be scheduled in the following areas:

Seminar Sessions:

1.0 Agricultural Productivity and Environmental Quality
2.0 Community Development in the 1970's
3.0 Our Obsolete Data Systems
4.0 The Government and Forest Resource Development
5.0 Institutional Economics

Sectional Meetings:

A. Agribusiness Research
B. Applied Welfare Economics
E. Continuing Education in the 1970's

Chairman of the contributed papers sessions is

Dr. Luther Tweeten
Department of Agricultural Economics
South Agricultural Building
Oklahoma State University
Stillwater, Oklahoma 74074

To be included in the program, titles of contributed papers must be submitted to Dr. Tweeten by May 15 and manuscripts must be in his hands by July 1. Contributed papers will be reported by title and author in the proceedings issue of the AJAE. Authors of contributed papers are invited to submit their papers to the Editor of the AJAE for possible publication.

AAEA Employment Service

An employment service for graduate students and professionals will be maintained in cooperation with the U.S. Employment Service at the annual meeting. Universities, government agencies, and industry are urged to list their employment vacancies with the AAEA. Individuals or organizations not members of the AAEA may obtain forms from Robert D. Emerson, Department of Food and Resource Economics, University of Florida, Gainesville 32601.

1972
NOMINEES
FOR OFFICES OF THE AAEA

PRESIDENT

James Plaxico, Oklahoma State University

and

Kenneth Tefertiller, University of Florida

DIRECTORS

I

Kenneth Ogren, Foreign Agriculture Service, USDA

and

Kenneth Farrell, Economic Research Service, USDA

II

Chester Baker, University of Illinois

and

Lehman Fletcher, Iowa State University

Correcting Some Errors of the Previous Editor

Co-winner of the award for the outstanding article published in the *Journal* was Walter P. Falcon who authored "The Green Revolution: Generations of Problems," *Am. J. Agr. Econ.* 52:698–710, Dec. 1970. Regretfully, Dr. Falcon's name was omitted from the list of award recipients in the December 1971 AJAE (p. 931).

The 82 articles mentioned in the Editor's report (December 1971, p. 930) were of coures *refereed* not *refered.*

Varden Fuller

University of Guelph

As of July 1, 1971, the Departments of Agricultural Economics and Extension Education were joined to form the School of Agricultural Economics and Extension Education. While the established programs of the former Departments will be continued, the School will facilitate a new focus and greater emphasis on teaching and research in social and economic issues concerning rural people.

On all matters relating to the School and its programs please write to:

Professor T. K. Warley, Director
School of Agricultural Economics
and Extension Education
University of Guelph
Guelph, Ontario, Canada

Back Issues Needed

The Secretary-Treasurer of the AAEA is authorized until September 1, 1972, to pay \$1.00 each for any of the issues of the AJAE (Formerly JFE) listed below. Other miscellaneous issues will be accepted only on a gratuitous basis, but the AAEA will pay the shipping cost. If you have complete sets or continuous volumes of some duration, please inquire of our total needs before breaking the set up.

YEAR	VOLUME	ISSUES	YEAR	VOLUME	ISSUES
1919	1	1,2,3,4	1950	32	1
1920	2	1,2,3,4	1951	33	1,2,3
1921	3	1,2,3,4	1952	34	1,5
1922	4	1,2,3,4	1953	35	1
1923	5	1,2,3,4	1954	36	1,2,3,4
1924	6	1,2,3,4	1955	37	1,2,3,4,5
1925	7	1,2,3,4	1956	38	1,2,3,5
1926	8	1,2,3,4	1957	39	1,2,3,4,5
1927	9	1,2,3,4	1958	40	1,2,3
1928	10	2,3,4,HB	1959	41	1,3
1935**	17	1	1960	42	1,3,4,5
1940	22	1	1961	43	1,2,3,4,5
1941	23	1	1962	44	1,2,3
1942	24	2	1963	45	1,2,3,4,5
1943	25	1,2,3,4	1964	46	1,2,3,4,5
1944	26	2,3,4	1965	47	1,3
1945	27	1,2,3,4	1966	48	2
1946	28	1,2,3,4	1967	49	1-pt. 1 & pt. 2
1947	29	1,2,3,4	1968	50	5
1948	30	1,2,3	1970**	52	1

** These Issues Needed Immediately

Journals should be sent prepaid to John C. Redman, Secretary-Treasurer, AAEA, Dept. of Agricultural Economics, University of Kentucky, Lexington, Kentucky 40506.

American Bibliography of Agricultural Economics

During 1971 the *American Bibliography of Agricultural Economics* was sent free of charge to domestic libraries, sustaining members of the Association, Departments of Agricultural Economics, and selected agencies of the government. Beginning with Volume II (1972), the bibliography will be available only by subscription at the rate of $10 per year. You are encouraged to subscribe to help put this activity on a sustaining basis. Direct your subscriptions to John C. Redman, Secretary-Treasurer, AAEA, University of Kentucky, Lexington, Kentucky 40506.

TVA-SSA Symposium

The Tennessee Valley Authority and the Social Security Administration are sponsoring a symposium, "The Labor Force: Migration, Earnings, and Growth—Socioeconomic Analysis Using the Social Security Work History Sample," June 22–23 at Muscle Shoals, Alabama. Further information can be obtained from Wesley G. Smith, TVA, F-120 NFDC, Muscle Shoals, Alabama 35660; telephone (205) 383–4631, Extension 393.

AAEA COMMITTEE STRUCTURE, 1971–1972

AWARDS COMMITTEE

Chester Baker, Chairman, Illinois, 1970

Distinguished Undergraduate Teacher Award

John W. Malone, Jr., Chairman, Nevada, 1968
David Armstrong, Michigan State, 1970
Robert L. Christensen, Massachusetts, 1970
Thomas L. Frey, Nebraska, 1971
John W. Goodwin, Oklahoma State, 1971
Milton F. Snodgrass, California Polytechnic, 1969
Jack C. Thompson, Georgia, 1970
Michael L. Peacock, Texas Tech., 1971 (student)

Extension Award

Gene McMurtry, Chairman, Virginia Polytechnic, 1969
John S. Bottum, ES, USDA, 1970
William M. Carroll, Pennsylvania State, 1971
Martin K. Christianson, Minnesota, 1971
M. Lloyd Downen, Tennessee, 1971
Duane E. Erickson, Illinois, 1971
Henry Meenan, Arkansas, 1970
Jean B. Wyckoff, Oregon State, 1970

Published Research Award

John O. Gerald, Chairman, ERS, USDA, 1969
W. R. Butcher, Washington State, 1970
Dale E. Butz, FS Services, Inc., 1971
Joseph Havlicek, Jr., Purdue, 1969
J. Charles Headley, Missouri, 1971
B. V. Lessley, Maryland, 1970
W. E. Martin, Arizona, 1970
Donald S. Moore, Texas A&M, 1971
W. C. Motes, EDD, ERS, USDA, 1970
Brian B. Perkins, Guelph, 1971
Shlomo Reutlinger, International Bank for Reconstruction and Development, 1971
J. A. Seagraves, North Carolina State, 1970
Howard Williams, Ohio State, 1969

Master's Thesis Award

Robert W. Herdt, Chairman, Illinois, 1970
David J. Allee, Cornell, 1970
Dale Anderson, North Dakota State, 1969
Hugh L. Cook, Wisconsin, 1971
James R. Gray, New Mexico State, 1971
Thomas F. Hady, ERS, USDA, 1969
J. Steve Lytle, Clemson, South Carolina, 1971
Ronald D. Knutson, Purdue, 1971
Tsoung-Chao Lee, Connecticut, 1971
Wallace Rehberg, Washington State, 1970
Robert Rizek, ARS, USDA, 1969
Edward H. Ward, Montana State, 1971
T. T. Williams, Southern U., Louisiana, 1970

Ph.D. Dissertation Award

Joseph C. Purcell, Chairman, Georgia, 1969
W. Burl Back, ERS, USDA, 1969
Dan W. Bromley, Wisconsin, 1970
William G. Brown, Oregon State, 1971
Donald E. Farris, Texas A&M, 1970
Marvin Hayenga, Michigan State, 1971
R. A. Hinton, Illinois, 1970
Verner G. Hurt, Mississippi State, 1969
Alain de Janvry, California, 1971
George M. Ladd, Iowa State, 1971
Frank Orazem, Kansas State, 1970
Wayne Purcell, Oklahoma State, 1969
Fred H. Tyner, Florida, 1970

PROFESSIONAL ACTIVITIES COMMITTEE

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Linley E. Juers, ERS, USDA, 1971
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Kenneth R. Tefertiller, Florida, 1968

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Eldon E. Weeks, ERS, USDA, 1971
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Glenn L. Johnson, Michigan State, 1970
Maurice M. Kelso, Arizona, 1968
Nathan M. Koffsky, Chevy Chase, Maryland, 1969
Don Paarlberg, USDA, 1971

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John C. Redman, Chairman, Kentucky, 1969
Dale E. Butz, FS Services, Inc., 1970
C. D. Kearl, Cornell, 1958

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Postwar Literature Review Committee

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Peter G. Helmberger, Wisconsin, 1969
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Maurice M. Kelso, Arizona, 1967
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Edward W. Tyrchniewicz, Manitoba, Winnipeg, 1969
Melvin L. Upchurch, ERS, USDA, 1967

Student Affairs Committee

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Daniel D. Badger, Oklahoma State, 1970
Donald J. Epp, Pennsylvania State, 1969
A. Robert Koch, Rutgers, 1969
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Sherwood O. Berg, Chairman, Minnesota, 1971
S. Kent Christensen, National Assn. of Food Chains, 1965
Joseph H. Marshall, Cotton Producers Association, 1970
Charles R. Sayre, Staple Cotton Cooperative Association, 1965
Raymond E. Seltzer, Dunlap and Associates, Inc., 1970
Lauren K. Soth, Des Moines Register and Tribune, 1965
Roy G. Stout, Coca Cola, Atlanta, 1970

TELLERS COMMITTEE

Bruce R. Beattie, Kentucky, 1970
A. Frank Bordeaux, Jr., Kentucky, 1970

VISITING PROFESSOR COMMITTEE

R. J. Hildreth, Chairman, Farm Foundation, 1969
Emiel W. Owens, Houston, 1969
John E. Thompson, South Dakota State, 1969
Andrew Vanvig, Wyoming, 1969

AAEA Representative to the Agricultural Development Council Research and Training Network Program (ADC/RTN)

Carl K. Eicher, Michigan State

AAEA Representative to the American Society of Agronomy

C. R. Hoglund, Michigan State

AAEA Representative to Council for Agricultural Science and Technology

George E. Brandow, Pennsylvania State

AAEA Representative to the National Bureau of Economic Research

Harold G. Halcrow, Illinois

AAEA Representative to the National Research Council

George E. Brandow, Pennsylvania State

AAEA Representative to the Bureau of Census Advisory Committee on Agricultural Statistics

James T. Bonnen, Michigan State

ASA-AAEA Joint Advisory Committee on Agricultural Statistics

James T. Bonnen, Chairman, Michigan State
George G. Judge, Champaign, Illinois
Dean E. McKee, Deere & Company

U. S. Council of the International Association of Agricultural Economics

Vernon W. Ruttan, Chairman, Minnesota
Harold F. Breimyer, Missouri
Max Myers, South Dakota State
Melvin L. Upchurch, ERS, USDA

Ad Hoc Committee on Demand for Agricultural Economists

Dale Hathaway, Chairman, Michigan State
John Helmberger, Minnesota
Louis Upchurch, Florida
Thomas Veblen, Cargill & Company
D. Gale Johnson, Chicago

Local Arrangements, Winter, 1971

Fred A. Wiegmann, Louisiana State University

Local Arrangements, Summer, 1972

Kenneth Tefertiller, University of Florida
James Pearson, University of Florida

News Notes

UNIVERSITY OF ARIZONA

APPOINTMENTS: **Thomas Archer,** research associate; **John Flinn,** University of Guelph, visiting assistant professor; **N. Gene Wright,** formerly extension economist, New Mexico State, research associate.

RESIGNATION: **William Gotsch,** to the Idaho Water Resource Board, Boise.

RETIREMENT: **Maurice Kelso,** also named professor emeritus.

UNIVERSITY OF CALIFORNIA, DAVIS

LEAVE: **Gordon A. King,** sabbatical leave for study and research at the Department of Applied Economics, University of Cambridge, England.

RETIREMENT: **D. Barton DeLoach,** professor, after 13½ years service.

UNIVERSITY OF CHICAGO

APPOINTMENTS: **D. Gale Johnson,** chairman, Department of Economics; **Robert Evenson,** Yale, visiting professor.

AWARD: **George S. Tolley,** a Ford Foundation Faculty Fellowship for 1972.

CLEMSON UNIVERSITY

APPOINTMENT: **Dan Lucien McLemore,** Ph.D. Clemson, assistant professor in the Agricultural Economics Extension Service.

CORNELL UNIVERSITY

APPOINTMENT: **Earl H. Brown,** professor, appointed associate director of Resident Instruction for the College of Agriculture and Life Sciences.

ECONOMIC RESEARCH SERVICE

APPOINTMENT: **Quentin M. West,** administrator.

UNIVERSITY OF HAWAII

APPOINTMENTS: **Frank S. Scott, Jr.,** chairman, Department of Agricultural and Resource Economics; **William J. Staub,** Ph.D. Missouri, associate professor and associate researcher in the Food Institute.

UNIVERSITY OF ILLINOIS

LEAVES: **L. P. Fettig,** sabbatical leave, six months ending July 31, 1972; **W. N. Thompson,** on leave with the National Institute of Development Administration, Bangkok, Thailand, for four months, ending mid-June, 1972.

UNIVERSITY OF MARYLAND

APPOINTMENT: **William Bellows,** Ph.D. Massachusetts, faculty research associate in resource economics.

LEAVES: **Jarvis L. Cain,** one year's sabbatical, University of Hawaii; **Billy V. Lessley,** sabbatical leave, February-August 1972.

RETIREMENT: **Arthur B. Hamilton,** retired as assistant to the Dean and has been awarded emeritus status in the Dept. of Agricultural and Resource Economics.

RETURNS: **John R. Moore** has returned from an 18-month leave with the Ford Foundation in New Delhi, India: **John W. Wysong** has returned from leave in Yugoslavia and the United Kingdom.

UNIVERSITY OF MASSACHUSETTS

APPOINTMENTS: **Thomas M. Bell,** assistant professor of resource economics; **N. Eugene Engel,** head of the Department.

LEAVE: **John H. Bragg,** Institute of Administration, University of Ife, Nigeria, for two years.

MICHIGAN STATE UNIVERSITY

REASSIGNMENT: **Thomas J. Manetsch,** reassigned from the Korean Agricultural Sector Study (KASS) project to work on a simulation model of the Korean agricultural economy.

UNIVERSITY OF MINNESOTA

APPOINTMENTS: **John C. Anderson,** M.S. Michigan State, research specialist; **John W. Schamper,** Ph.D. Wisconsin, research associate.

RETURN: **Osama A. Al-Zand,** assistant professor, has returned from a 3-year assignment for the Minnesota-Tunisia project.

MISSISSIPPI STATE UNIVERSITY

APPOINTMENTS: **Warren C. Couvillion, Sr.,** Ph.D. Tennessee, assistant professor; **G. Wayne Malone,** Ph.D. Purdue, assistant professor.

MONTANA STATE UNIVERSITY

HONOR: **Richard J. McConnen,** professor and de-

partment head, chosen president-elect of the Western Agricultural Economics Association.

UNIVERSITY OF NEBRASKA

APPOINTMENT: **Leslie Sheffield,** Ph.D. Nebraska, coordinator, Irrigation Development Program, Agricultural Extension Service and Agricultural Experiment Station.

UNIVERSITY OF NEVADA, RENO

APPOINTMENT: **Chauncey T. K. Ching,** formerly with the University of New Hampshire, associate professor in the Division of Agricultural and Resource Economics.

NORTH CAROLINA STATE UNIVERSITY

APPOINTMENT: **Leon E. Danielson,** assistant professor.

OHIO STATE UNIVERSITY

RETURN: **S. S. Johl,** chairman of the Department of Economics and Sociology, Punjab Agricultural University, Ludhiana, India, has returned to India after 15 months as a visiting professor here.

OKLAHOMA STATE UNIVERSITY

APPOINTMENT: **Richard E. Just,** Ph.D. candidate University of California at Berkeley, assistant professor.

AWARD: **Alan R. Tubbs** won the $1,000 Oklahoma Bankers Association Award to attend the Graduate School of Banking.

REASSIGNMENT: **George Cross,** to SCS, USDA, Syracuse, N.Y., as planning economist, following completion of master's degree work.

PURDUE UNIVERSITY

APPOINTMENTS: **Lawrence J. Brainard,** assistant professor of agricultural economics in international programs; **John R. Gordon,** assistant professor in community development; **Gerald A. Harrison,** assistant professor in production economics; **Kohei Kobayashi,** visiting professor; **Alberto R. Musalem,** visiting professor in agricultural trade and development.

HONOR: **J. Carroll Bottum** received the Epsilon Sigma Phi National Certificate of Recognition.

LEAVES: **Ronald D. Knutson,** Marketing and Consumer Services, USDA, one year; **William L. Miller,** Soil Conservation Service, USDA, one year; **Don Paarlberg,** director, Agricultural Economics, USDA; **Robert E. Schneidau,** Department of Agricultural Economics, Oregon State, one year; **Robert W. Taylor,** Purdue-Brazil project, Vicosa, Brazil, two years.

RETIREMENTS: **J. Carroll Bottum,** Hillenbrand Distinguished Professor of Agricultural Economics, after 42 years of service; **Noah S. Hadley,** professor, after 41 years of service, 15 years as county agent and 26 years as farm management specialist.

RETURNS: **J. H. Atkinson,** professor, after two years as chief-of-party with the Purdue-Brazil project in Vicosa; **H. Evan Drummond,** graduate assistant, after two years with the Purdue-Brazil project; **G. Edward Schuh,** professor, after one and a half years as program advisor to the Ford Foundation in Rio de Janeiro; **T. Kelley White, Jr.,** associate professor, after two years with the Purdue-Brazil project.

TRANSFERS: **William G. Bursch,** from FPED, ERS, USDA, to Purdue Swine Subsector Study as assistant professor; **Lawrence A. Duewer,** from MED, ERS, USDA, to the Purdue Swine Subsector Study as assistant professor.

UNIVERSITY OF WISCONSIN

APPOINTMENT: **Ronald E. Shaffer,** Ph.D. Oklahoma, assistant professor in the area of community development.

RETURN: **Kenneth H. Parsons,** after three years at the University of Ife, Nigeria, on the USAID/Wisconsin project.

OTHER APPOINTMENTS

Bruce L. Anderson, M.S. Purdue, independent researcher, Lantbrukshogskolan, Sweden.

Mohd Sheffie Bakar, M.S. Purdue, marketing economist, Food Technology Research and Development Center, Kuala Lumpur, Malaysia.

Ivan W. Bartling, M.S. Purdue, grain merchandiser, Pillsbury, Wayne City, Illinois.

Michael D. Boehlje, Ph.D. Purdue, assistant professor of agricultural economics, Oklahoma State University.

Andres M. VonBuch, M.S. Purdue, economic consultant, Buenos Aires, Argentina.

Clark R. Burbee, Ph.D. candidate Minnesota, to the Poultry Group, MED, ERS, USDA, Washington.

Keith M. Byergo, M.S. Purdue, deputy food agricultural officer, SUAOD, Ankara, Turkey.

Douglas M. Byers, Ph.D. Purdue, economist, Canada Department of Agriculture, Ottawa.

Richard Wayne Cartwright, Ph.D. Purdue, principal marketing research officer, Massey University, New Zealand.

A. John DeBoer, Ph.D. candidate Minnesota, to the Faculty of Agriculture, University of Queensland, Brisbane, Australia.

Herman Delvo, Ph.D. Nebraska, to the ERS, FPED, Washington.

Warren J. Enger, M.S. Wisconsin, program technical representative, ACTION, Kuala Lumpur, Malaysia.

Barry L. Flinchbaugh, Ph.D. Purdue, assistant professor of economics, Kansas State University.

A. Leroy Frederick, Ph.D. Purdue, extension grain marketing specialist, Kansas State University.

Thomas F. Funk, Ph.D. Purdue, assistant professor of agricultural economics, University of Guelph.

Richard L. Gady, Ph.D. Purdue, economist, Cleveland Federal Reserve Bank.

Terrence F. Glover, Ph.D. Purdue, assistant professor, Ohio State University.

Lyndon E. Goodridge, Ph.D. Purdue, assistant professor, Rochester Institute of Technology, Rochester, N.Y.

Harold M. Harris, Jr., Ph.D. Purdue, assistant professor, Virginia Polytechnic Institute and State University.

Paul J. Hooker, Ph.D. Florida, assistant professor, has accepted an 18-month assignment with the Guyana/UF contract in Georgetown, Guyana.

Peter J. Kuch, Ph.D. candidate Minnesota, to the Faculty of the University of Western Ontario, London, Ontario, Canada.

Gary Lentz, Ph.D. Nebraska, to the Farm Economics division of the Cooperatives and Statistics Branch, Ontario Department of Agriculture, Guelph.

LeRoy Luft, Ph.D. Nebraska, to Montana State University as extension economist.

John William McAlhany, Ph.D. Clemson, assistant professor of economics at The Citadel, Charleston, S.C.

Benny R. McManus, Ph.D. Purdue, associate professor of agricultural economics and rural sociology, University of Tennessee.

Tommy Cleveland Meadows, Ph.D. candidate Clemson, assistant professor of economics, Mars Hill College, Mars Hill, N.C.

Kerry A. Miller, M.S. Purdue, field salesman, Geigy Chemicals, Ardsley, N.Y.

Jorge Elizondo-Montalvo, M.S. Purdue, departmental administrator, Monterrey Institute of Technology, Mexico.

Luc Muermans, Ph.D. Nebraska, to the Department of Economics, University of Belgium.

Larry L. Nelson, Ph.D. Purdue, executive vice president, Snyder Associates, Inc., West Lafayette, Indiana.

Jacques Pasquier, Ph.D. Purdue, professor, University of Fribourg, Switzerland.

Neil H. Pelsue, Jr., Ph.D. Purdue, assistant professor, Department of Agricultural and Resource Economics, University of Maine.

John T. Porter, Ph.D. Purdue, marketing economist, FED, USDA.

Marshall Burrell Richardson, Ph.D. Clemson, to East Tennessee State University as assistant professor of economics.

Sol. Sinclair, professor of agricultural economics and director of the Natural Resources Institute, University of Manitoba, recently was appointed chairman of the Advisory Committee of the Freshwater Fish & Marketing Corp.

Bernard H. Sonntag, Ph.D. Purdue, economist, Canada Agriculture Research Station, Lethbridge, Alberta.

Igusti B. Teken, Ph.D. Purdue, lecturer, Institut Pertanian Bogor, Indonesia.

H. Don Tilmon, Ph.D. Purdue, assistant professor and associate director of M.B.A. Program, Lynchburg College, Lynchburg, Virginia.

Robert W. Winters, Ph.D. Purdue, teacher, Coronado High School, Scottsdale, Arizona.

OBITUARY

Theo H. Ellis, 56, retired agricultural economist and former director of the Auburn University Computer Center, died Oct. 20, 1971, in the Veterans Administration Hospital, Gainesville, Florida.

A native of Alachua, Fla., Dr. Ellis graduated from the University of Florida and received his Ph.D. from the UF in 1957. He served as extension economist at the University of Arizona and as assistant agricultural economist at North Dakota Agricultural College. In 1958 he joined the USDA staff at Auburn University as a cooperative research employee in the Department of Agricultural Economics. During 1960 and 1961 he was associate director of the Auburn University computer center and associate agricultural economist in the Department of Agricultural Economics. He was appointed acting director of the Auburn computer center in 1961.

DOCTORAL DEGREES IN AGRICULTURAL ECONOMICS CONFERRED IN 1971, BY SUBJECT AREA

I. AGRICULTURAL ECONOMICS, GENERAL

Metin Berk, B. S. Middle East Technical University, 1964; M.S. Iowa State University, 1968; Ph.D. Iowa State University, *Changing Structure of Iowa Farmland Ownership.*

Jose A. B. S. Girao, Superior Course of Agronomy, Institute of Agriculture, University of Lisbon, 1960; Engenheiro Agronomo, Institute of Agriculture, University of Lisbon, 1963; Ph.D. Cornell University, *The Impact of Income Instability on Farmers' Consumption and Investment Behavior. An Econometric Analysis.*

Daryll Eugene Ray, B. S. Iowa State University, 1965; Ph.D. Iowa State University, *An Econometric Simulation Model of United States Agriculture with Commodity Submodels.*

II. AGRICULTURAL FINANCE, CAPITAL, CREDIT

Bennie Eldred Beeson, Jr., B.S. Louisiana State University, 1959; M.S. Louisiana State University, 1965; Ph.D. University of Tennessee, *Management of Insurable Risk by East Tennessee Tobacco Farmers.*

Michael Dean Boehlje, B.S. Iowa State University, 1965; M.S. Purdue University, 1970; Ph.D. Purdue University, *Strategies for the Creation and Transfer of the Farm Firm Estate.*

Merle R. Buss, B.S. Oklahoma State University, 1965; M.S. Oklahoma State University, 1966; Ph.D. Oklahoma State University, *The Economics of Tax Management of the Types of Farm Organizations for Oklahoma Commercial Farms.*

John Oak Early, B. S. Ohio State University, 1950; M.S. Colorado State University, 1956; Ph.D. Ohio State University, *An Economic Analysis of Agri-Business Credit Sources and Uses in the Itapetininga and Sao Jose Do Rio Preto Areas, Sao Paulo, Brazil.*

Sung Hoon Kim, B. S. Seoul National University, 1963; M.S. University of Hawaii, 1968; Ph.D. University of Hawaii, *The Structure and Functioning of Rural Credit in Korea: An Empirical Analysis.*

George Edward Lee, B.S.A. University of Saskatchewan, 1960; M.S. University of Saskatchewan, 1963; Ph.D. Purdue University, *Exploitation of Information for Capital Accumulation Under Uncertainty.*

Benny Ray McManus, B.S. Auburn University, 1958; M.S. Auburn University, 1963; Ph.D. Purdue University, *Credit Reserves for Midwestern Farmers.*

Michael A. Perelman, B. A. University of Michigan, 1961; M.A. San Francisco State University, 1966; Ph.D. University of California at Berkeley, *Investment Theory in Light of Expectations.*

Alan Roy Tubbs, B.S. Iowa State University, 1966; M.S. Cornell University, 1968; Ph.D. Cornell University, *Capital Investments in Agricultural Marketing Cooperatives: Implications for Farm Firm and Cooperative Finance.*

III. AGRICULTURAL LABOR: RURAL MANPOWER

John Hogarth Cleave, B.Sc. University of London, 1952; M.A. Stanford University, 1968; Ph.D. Stanford University, *Labour in the Development of African Agriculture: The Evidence from Farm Surveys.*

Charles M. Cuskaden, B.S. Purdue University, 1961; M.S. University of Kentucky, 1963; Ph.D. Michigan State University, *Worker Productivity in Harvesting Michigan Apples.*

Terrence Frank Glover, B.S. Utah State University, 1965; M.S. Utah State University, 1966; Ph.D. Purdue University, *Seasonal Employment of Hired Labor in U.S. Agriculture.*

Gerald Emil Schluter, B.S. Iowa State University, 1964; M.S. Iowa State University, 1966; Ph.D. Iowa State University, *An Estimation of Agricultural Employment Through an Input-Output Study.*

IV. AGRICULTURAL INCOME

Leonard L. Bull, B.S. Iowa State University, 1961; M.S. Iowa State University, 1966; M.A. University of Wisconsin, 1968; Ph.D. University of Wisconsin, *An Economic Analysis of Rural Wisconsin Household Income.*

Meir Chayat, B.Sc. Hebrew University, 1959; M.Sc. Hebrew University, 1962; Ph.D. Cornell University, *Bargaining Power to Farmers and Its Welfare Effects: A Case Study of the Egg Production Industry.*

V. AGRICULTURAL PRODUCTS: DEMAND, SUPPLY, AND PRICE

Walter Joseph Armbruster, B.S. Purdue University, 1962; M.S. Purdue University, 1964; Ph.D. Oregon State University, *Simulation of Farm Bargaining Board Policies in the Western Late Potato System.*

Hector R. Barreyro, B.S. Ingeniero Agronomo Universidad de La Plata; M.S. Texas A&M University; Ph.D. Texas A&M University, *An Analysis of the Supply of Grain in the Pergamino Region of Argentina: A Dynamic Programming Approach.*

Abdul Basit, B.Sc. University of the Punjab, 1961; M.Sc. West Pakistan Agricultural University, 1963; Ph.D. Washington State University, *Projections of Demand and Supply of Wheat and Rice in Pakistan.*

Warren Carl Couvillion, Sr., B.S. Louisiana State University, 1962; M.S. Louisiana State University, 1967; Ph.D. University of Tennessee, *A Critical Analysis of Vertical Price Distortion in the Pork Sector.*

Paul Duane, B.S. University of Sydney, Australia, 1957; Ph.D. North Carolina State University, *Analysis of Wool Price Fluctuations: An Economic Study of Price Formation in a Raw Material Market.*

Dan Maxwell Etherington, B.A. Rhodes University, Grahamstown, South Africa, 1960; M.S. Cornell University, 1962; M.A. Stanford University, 1968; Ph.D. Stanford University, *An Econometric Analysis of Smallholder Tea Production in Kenya.*

Frederick Daniel Gray, B.S. University of Connecticut, 1952; M.S. University of Maryland, 1960; Ph.D. University of Maryland, *Sweetner Consumption and Utilization Patterns in the U.S.: Past Trends and Relationships, and Prospects for 1980 and 2000.*

Duane Hacklander, B.S. University of Minnesota, 1960; M.S. University of Minnesota, 1962; Ph.D. Michigan State University, *Price Relationships Among Selected Wholesale Beef and Pork Cuts.*

Zuhair Hassan, B.Sc. West Pakistan Agricultural University, 1964; M.S. University of Kentucky, 1966; Ph.D. University of Missouri, *Estimation of Demand Parameters: An Empirical Analysis of Consumer Behavior in the United States.*

David Eugene Kenyon, B.S. Washington State University, 1966; M.S. University of California at Davis, 1968; Ph.D. University of California at Davis, *Optimum Utilization and Intraseasonal Allocation of California Apple Production.*

Dan Lucien McLemore, B.S. Presbyterian College, 1966; M.S. Clemson University, 1969; Ph.D. Clemson University, *Wholesale Demand Functions for Fresh Peaches in Twenty-Three Markets.*

Luc Muermans, B.S. University of Louvain, Belgium; Ph.D. University of Nebraska, *Demand for Feed Wheat by Nations with Projections to 1980.*

Vijay Kumar Pandey, B.S. Uttar Pradesh Agricultural University, 1964; M.S. Uttar Pradesh Agricultural University, 1966; Ph.D. University of Illinois, *Intertemporal Pricing and Output Allocation of Major Foodgrains in India.*

Neil H. Pelsue, Jr., B.S. University of Vermont, 1963; M.S. University of Massachusetts, 1967; Ph.D. Purdue University, *An Economic Analysis of the Impact of Emerging Grade A Milk Supplies Upon the North Central Dairy Industry.*

Gordon Clyde Rausser, B.S. Fresno State College, 1965; M.S. University of California at Davis, 1968; Ph.D. University of California at Davis, *A Dynamic Econometric Model of the California-Arizona Orange Industry.*

Igusti Bagus Teken, M.S. University of Kentucky, 1962; Ph.D. Purdue University, *Supply of and Demand for Indonesian Rubber.*

VI. Cooperatives and Cooperation

Harold Wayne Lough, B.S. Purdue University, 1966; Ph.D. Oregon State University, *The Relationship between Farm Supply Cooperatives' Economic Performance and Their Organizational Power Centers' Level of Motivation to Achieve Objectives.*

VII. Economic Development, Growth and Planning

Sung Hwan Ban, B.S. Seoul National University, 1955; M.S. Seoul National University, 1958; M.S. University of Minnesota, 1963; Ph.D. University of Minnesota, *The Long-Run Productivity Growth in Korean Agricultural Development, 1910–1968.*

Martin Billings, B.A. Tufts University, 1956; Ph.D. Michigan State University, *Economics of Commercial Egg Production in Eastern Nigeria.*

Nelson Lawrence Bills, B.S. Michigan State University, 1963; M.S. West Virginia University, 1967; Ph.D. Washington State University, *A Comparative Study of Public Investments in Three Rural Washington Communities.*

J. James Bucknall, B.Sc. London University, 1963; M.Sc. University of Guelph, 1965; M.B.A. University of British Columbia, 1967; M.A. University of Wisconsin, 1969; Ph.D. University of Wisconsin, *An Appraisal of Some of the Developmental Impacts of the Kenya National Trading Corporation.*

Parker Ditmore Cashdollar, B.S. University of Tennessee, 1964; M.S. University of Tennessee, 1970; Ph.D. University of Tennessee, *An Economic Analysis of Crops and Land Use Localizations in the Tungabhadra Irrigation Project of Mysore State, India.*

Ali Mohammad Chaudhry, B.Sc. University of Punjab, 1945; M.S. Cornell University, 1968; Ph.D. Washington State University, *Economic Impacts of Wheat Yield Increases in West Pakistan.*

Basil Glasford Coley, B.S. A&T College, 1961; M.S. The Pennsylvania State University, 1962; Ph.D. University of Illinois, *A Comparative Analysis of Some Factors Affecting Economic Growth in Jamaica and Puerto Rico, 1957–1967.*

Theodore E. Doty, B.A. Iowa State University, 1958; Ph.D. Washington State University, *Washington State University in West Pakistan 1954–1969: An Evaluation of Technical Assistance to Higher Education for Agricultural and Economics Development.*

John Gerald Feaster, B.S.A. University of Florida, 1964; M.S.A. University of Florida, 1966; Ph.D. University of Kentucky, *An Analysis of the Relationship between Infrastructure and Agricultural Development in Caqueta, Colombia.*

Donald Stewart Ferguson, B.S. Cornell University, 1958; M.S. Cornell University, 1967; Ph.D. Cornell University, *The Economics of Tick Borne*

Disease Control in Tropical Africa: The Case of Uganda.

David Green, B.C. University of Leeds, 1954; B.S. University of Leeds, 1960; M.S. University of Kentucky, 1965; Ph.D. Michigan State University, *Agricultural Mechanization in Ethiopia: An Economic Analysis of Four Case Studies.*

Brooke Alexander Greene, B.S. New Mexico State University, 1961; M.S. University of Florida, 1965; Ph.D. Cornell University, *Rate of Adoption of New Farm Practices in the Central Plains, Thailand.*

Roger Wayne Hexem, B.S. South Dakota State University, 1961; M.S. University of Nebraska, 1964; Ph.D. Iowa State University, *Factors Affecting the Economic and Social Well-Being of Agriculturists in Less-Developed Countries and Agriculture's Contribution to General Economic Expansion.*

Audley Eugene Hileman, B.S. The Pennsylvania State University, 1959; M.S. North Carolina State University, 1962; Ph.D. University of Tennessee, *Time Lags in the Impact of Public Investment in Water Resources: The Tennessee Valley Region, 1936–1968.*

Harlan Hughes, B.S. University of Nebraska, 1962; M.S. University of Nebraska, 1964; Ph.D. University of Missouri, *Economic Analyses of Sugarcane Production in Sao Paulo, Brazil (Fornecedores 1968–69).*

John Horton Humphrey, B.S. University of London, 1962; Ph.D. University of California at Berkeley, *Resource Allocation and Income Distribution in Agriculture: A Case Study of an Irrigation Economy in Northwest Mexico and Its Implications for Development.*

Earl Kellogg, B.S. Kansas State University, 1963; Ph.D. Michigan State University, *A Temporal and Spatial Model to Assist in Evaluating Investments in the Nigerian Beef Distribution System.*

Thomas Harold Klindt, B.S. University of Missouri, 1967; M.S. University of Missouri, 1968; Ph.D. University of Kentucky, *Development of Procedures for Quantifying and Assessing the Economic Well-Being of Rural Areas.*

Abdul H. Maan, B.S. Punjab University, 1959; M.S. West Pakistan Agricultural University, 1963; Ph.D. The Pennsylvania State University, *Organization of Agricultural Resources in an Irrigated Area of West Pakistan.*

Joseph Gabriel Guy Motha, B.A. University of Ceylon, 1959; Ph.D. Stanford University, *The Impact of Import Policies on the Economy of Ceylon.*

Gholam Mustafa, B.S. Dacca University; M.S. Dacca University; Ph.D. Texas A&M University, *An Input-Output Model for the Texas Economy with Emphasis on Agriculture.*

Muhammad Naseem, B.Sc. University of the Punjab, 1950; M.Sc. University of London, 1954; Ph.D. University of California at Davis, *Small Farmers and Agricultural Transformation in Pakistan Punjab.*

William Charles Nelson, B.S. North Dakota State University, 1965; M.S. University of Arizona, 1966; Ph.D. Ohio State University, *An Economic Analysis of Fertilizer Utilization in Brazil.*

Athanasius Onwusaka Njoku, B.S. St. Edward's University, 1964; M.S. Oregon State University, 1966; Ph.D. University of Illinois, *Labor Utilization in Traditional Agriculture: The Case of Sierra Leone Rice Farms.*

Rodolfo E. Quiros, B.S. Cornell University, 1958; M.S. Michigan State University, 1962; Ph.D. University of Wisconsin, *Agricultural Development and Economic Integration in Central America.*

Jae H. Rhee, B.S. Seoul National University, 1958; M.S. University of Maine, 1964; Ph.D. The Pennsylvania State University, *Inflation and Agricultural Development in Korea.*

Mark Cabot W. Schroeder, B.S. University of Vermont, 1958; M.S. Cornell University, 1967; Ph.D. Cornell University, *The Impact of the Sonauli-Pokhara Highway on the Regional Income and Agricultural Production of Pokhara Valley, Nepal.*

Michael Schwartz, B.A. Harpur College, 1963; M.A. Clark University, 1969; Ph.D. University of Florida, *Input Productivity in Agriculture on the North Coast of Colombia.*

William Staub, B.S. University of Georgia, 1964; M.S. University of Georgia, 1966; Ph.D. University of Missouri, *Agricultural Development and Farm Employment: An Analysis of Factors Influencing the Employment of Family, Permanent, and Casual Labor on Farms in Two Developing Districts in India.*

Akram Mustafa Steitieh, B.S. American University of Beirut, 1957; M.S. Utah State University, 1967; Ph.D. Ohio State University, *Input Productivity and Productivity Change of the Crop Enterprise in Southern Brazil.*

Om Prakash Tangri, B.A. Punjab University, 1952; M.A. Punjab University, 1955; Ph.D. University of California at Berkeley, *India's Program for Agricultural Development: Uses and Effectiveness of Loans from U.S. Owned Rupee Funds Acquired through Sales of Agricultural Surpluses.*

Ronald Gene Trostle, B.S. Kansas State University, 1965; M.S. Kansas State University, 1968; Ph.D. Kansas State University, *An Analysis of Alternative Tax Sources to Finance Local Services in Kansas.*

Charles Vanderziel, B.S. California State Polytechnic College, 1964; M.S. University of Wyoming, 1966; Ph.D. University of Missouri, *Capital Productivity and Labor Utilization in Selected Development Projects.*

Joseph Louis Clovis Vellin, B.S. University of London, 1956; M.S. London School of Economics, 1965; Ph.D. Cornell University, *A Full Employ-*

ment Strategy for Agricultural Development in Mauritius.

VIII. Environmental Economics

Edward Barry Asmus, B.S. Colorado State University, 1964; M.S. Colorado State University, 1966; Ph.D. Montana State University, *Air Pollution Control: An Economic Analysis of a Montana Smelter's SO_2 Emissions.*

David M. Bell, B.S. University of Nebraska, 1965; M.S. University of Nebraska, 1967; Ph.D. Michigan State University, *The Impact of Air Pollution Abatement Activities of Coal-Burning Electric Power Generating Plants on the Fertilizer Industry.*

Kenneth Wayne Paxton, B.S. Louisiana State University, 1965; M.S. Louisiana State University, 1967; Ph.D. University of Tennessee, *Air Pollution and Property Values in Urban Areas.*

Jeffrey Mel Romm, B.S. University of California, Berkeley, 1964; M.S. Cornell University, 1968; Ph.D. Cornell University, *Nuclear Power, Cayuga Lake, and Economics.*

Gerald Eugene Smolen, B.S. Ohio State University, 1963; M.S. University of Tennessee, 1970; Ph.D. University of Tennessee, *The Costs Associated with Milk Packaging, Delivery, and Container Disposal for Four Container Types and the Policy Implications for the Knoxville, Tennessee, Area.*

Cesar F. Vergelin, License, Esc. S.E. Polit. y Sociales (Argentina), 1963; M.S. University of Wisconsin, 1967; Ph.D. University of Wisconsin, *Water Erosion in the Carcarana Water Shed: An Economic Study.*

IX. Food and Consumer Economics

Thomas A. Carlin, B.S. University of Georgia, 1965; M.S. University of Georgia, 1967; Ph.D. The Pennsylvania State University, *An Economic Analysis of the Predicted Effects of Alternative Family Assistance Programs on Selected Household Expenditures.*

Gary Fairchild, B.S. Ohio State University; M.S. Ohio State University; Ph.D. Texas A&M University, *Consumer Credit in the Retail Food Industry: Attitudinal Analysis and Market Segmentation.*

Ronald Dorance Lindmark, B.S. Ohio State University, 1961; M.S. University of Minnesota, 1963; Ph.D. Ohio State University, *Second Homes in Northwestern Wisconsin: A Study of the Owners and Their Use Patterns and Characteristics of the Second Home Structure.*

Robert E. Wunderle, B.S. Rutgers University, 1967; M.S. Cornell University, 1968; Ph.D. Cornell University, *Evaluation of the Pilot Food Certificate Program.*

X. General Economics

Rudolph Earl DePass, B.S. Virginia State College, 1956; M.S. The Pennsylvania State University, 1961; Ph.D. University of Maryland, *A Microanalytical Simulation of the United States Economy, 1961–1970.*

Julian Elery Holmes, B.S. Auburn University, 1962; M.S. Auburn University, 1965; Ph.D. University of Tennessee, *Costs and Returns from Golf Course Operations and Socioeconomic Factors Affecting Participation Rates in Golf.*

Robert T. Nash, B.S. Austin Peay State College; Ph.D. Texas A&M University, *The Impact of Changes in the Money Stock on the Agricultural Sector of the Economy.*

Earl Ray Peterson, B.S. North Dakota State University, 1958; M.S. Montana State University, 1963; Ph.D. Montana State University, *Decision Criteria Related to University Building Programs.*

Alan John Randall, B.S. University of Sydney, 1965; M.S. University of Sydney, 1969; Ph.D. Oregon State University, *Liability Rules, Transactions Costs, and Optimum Externality.*

XI. Human Resource Development

Andrew Gordon Cuthbertson, B.Ag.Econ. University of New England in Australia, 1966; M.E. North Carolina State University, 1968; Ph.D. North Carolina State University, *Occupational Training in the Trucking Industry.*

Friedrich W. von Fleckenstein, B.A. Reed College, 1961; M.S. University of Hawaii, 1965; Ph.D. University of Hawaii, *Adoption of Agricultural Innovations in a Northeastern Thai Village.*

William Jess Haley, B.S. Montana State University, 1964; M.S. Montana State University, 1967; M.E.S. North Carolina State University, 1969; Ph.D. North Carolina State University, *Human Capital Accumulation over the Life Cycle.*

Arthur Henry Smith, B.S. Cornell University, 1962; M.S. University of Arizona, 1964; Ph.D. University of Arizona, *A Socioeconomic Analysis of the Goals and Attitudes of Arizona Cattle Ranchers.*

XII. Industrial Organization

Allen Leroy Frederick, B.S. University of Nebraska, 1966; M.S. University of Nebraska, 1968; Ph.D. Purdue University, *Growth and Structural Change in Indiana Manufacturing Industries, 1959–1968.*

Johannes deGraaf, B.S. State Agricultural College, Dordrecht, Netherlands; B.Sc. McGill University; M.S. University of Massachusetts; Ph.D. University of Missouri, *Structural Changes in the Meat and Livestock Economy of the European Economic Community.*

J. Blake Imel, B.S. Purdue University, 1966; M.S. University of Wisconsin, 1969; Ph.D. University of Wisconsin, *Structure-Profit Relationships in the Food Processing Sector.*

Harold Loyd, B.S. Southwest Missouri State Col-

lege, 1966; M.S. University of Missouri, 1968; Ph.D. University of Missouri, *Alternate Methods of Coordination for Agricultural Producers.*

Emman O. Oyinlola, B.S. University of Nebraska, 1967; M.S. University of Nebraska, 1968; Ph.D. Iowa State University, *A Confirmatory Analysis of an Exploratory Factor Analytic Study of the Fluid Milk Bottling Firms in the North Central Region.*

XIII. MARKETING AND LOCATION

Gobind Shewakran Bhagia, B.A. Rjasthan University, India, 1962; M.S. Texas A&M University, 1967; Ph.D. Oregon State University, *An Economic Analysis of Cattle Feeding and Interregional Flows of Live and Carcass Beef.*

Robert Wallace Bohall, B.S. Cornell University, 1958; M.S. University of Connecticut, 1963; Ph.D. North Carolina State University, *Pricing Performance of the Marketing System for Selected Fresh Winter Vegetables.*

Kenneth L. Casavant, B.S. North Dakota State University, 1965; M.S. North Dakota State University, 1967; Ph.D. Washington State University, *An Economic Evaluation of the Competitive Position of Puget Sound Ports Versus Columbia River Ports for Pacific Northwest Wheat Exports.*

Muhammad Aslam Chaudhary, B.S. Government College, 1962; M.A. Punjab University, 1964; Ph.D. Michigan State University, *An Analysis of the Performance of Fertilizer Distribution System in West Pakistan.*

Wallace Clayton Dunham, B.S. University of Vermont, 1952; M.S. Ohio State University, 1956; Ph.D. Cornell University, *The Role of National Trade Associations in the Food Industry.*

Richard Francis Fallert, B.S.A. University of Missouri, 1958; M.S. University of Missouri, 1959; Ph.D. Purdue University, *An Analysis of Buyer-Seller Relations Between Food Chains and Fluid Milk Processors in the North Central Region.*

Jeremiah E. Fruin, B.S. University of Illinois, 1958; M.S. University of Illinois, 1959; Ph.D. University of California at Berkeley, *A Linear Programming Model of a Multiplant Tomato Packing Firm.*

Harold Monroe Harris, Jr., B.S. Auburn University, 1961; M.S. Auburn University, 1965; Ph.D. Purdue University, *The Economic Outlook for the Independent Dairy Company.*

Delmer Helgeson, B.S. North Dakota State University, 1958; M.S. North Dakota State University, 1960; Ph.D. University of Nebraska, *Cost Implications of Multiple-Product Farm Supply Retailing.*

Dennis R. Henderson, B.S. Ohio State University, 1965; Ph.D. Michigan State University, *Fertilizer Consumption and Industry Adjustment.*

Ralph Johnson, B.S. University of Nebraska, 1948; M.S. University of Nebraska, 1961; Ph.D. University of Nebraska, *An Economic Evaluation of Alternative Marketing Methods for Fed Cattle.*

Madjid Koopahi, B.S. Tehran University, Iran, 1959; M.A. North Carolina State University, 1968; Ph.D. The Pennsylvania State University, *Analysis of the Performance of Small Fluid Milk Processing Firms in Pennsylvania.*

William Kost, B.S. Western Illinois University, 1963; M.S. Michigan State University, 1967; Ph.D. Michigan State University, *Trade Flows in the Grain-Livestock Economy of the European Economic Community.*

Olivier Lafourcade, B.S. Ecole Nationale Superieure Agronomique, Rennes, France, 1967; M.S. University of Maryland, 1969; Ph.D. University of Maryland, *Analysis of Optimal Marketing Strategies for the Poultry Industry in Delmarva.*

Richard Wynn Lichty, B.A. Kansas State Teachers College, 1965; M.A. Kansas State University, 1967; Ph.D. Kansas State University, *An Analysis of Alternative Fresh and Frozen Meat Distribution Systems.*

Nicholas Brier Lilwall, B.S. University of Leeds, 1964; M.S. University of Illinois, 1970; Ph.D. University of Minnesota, *Technological Organizational and Spatial Factors as Determinants of Optimum Plant Size in the Cheddar Cheese Manufacturing Industry.*

John George Litschauer, B.S. Montana State University, 1961; M.S. Montana State University, 1963; Ph.D. University of California at Berkeley, *Economies of Scale in California's San Joaquin Valley Poultry Feed Milling Industry.*

James I. Mallett, B.S. Oklahoma State University; M.S. Texas A&M University; Ph.D. Texas A&M University, *An Economic Evaluation of Verticle Coordination in the Feed-Grain-Livestock-Meat Industry of the El Paso-Las Cruces Subregion.*

John William McAlhany, B.A. Furman University, 1964; M.S. Clemson University, 1968; Ph.D. Clemson University, *An Economic Determination of the Optimum Size Cotton Gin for South Carolina.*

Diane June Schoening Miracle, B.A. Stanford University, 1955; M.A. Stanford University, 1962; Ph.D. Stanford University, *The Role of the Egg Futures Market in the Egg Economy: 1940 to 1966.*

Theodore Franklin Moriak, A.B. College of St. Thomas, 1964; M.S. University of California at Davis, 1968; Ph.D. University of California at Davis, *Coordinating Bread Distribution: A Simulation of Interfirm Behavior.*

Alwar Najappa Krishna Murthy, B.S. Madras State College, 1955; M.S. University of Tennessee, 1963; Ph.D. University of Tennessee, *Developing and Restructuring Regulated Markets in Mysore State, India: An Alternative for Improving the Efficiency of Marketing Food Grains.*

Ki-Tai Pae, B.S. Kyungpook National University,

Korea, 1959; M.S. Kyungpook National University, 1961; B.A. Kyungpook National University, 1963; M.A. Kyungpook National University, 1965; Ph.D. University of Connecticut, *An Interregional and Intertemporal Activity Analysis of the United States Potato Industry.*

John Tappan Porter, B.S.A. Cornell University, 1958; M.S. Michigan State University, 1961; Ph.D. Purdue University, *Economic and Marketing Potential for Expansion of Horticultural Production in the Lower Wabash Valley.*

James J. Ruane, B.S. University College, Dublin, 1966; M.S. University College, 1967; Ph.D. The Pennsylvania State University, *Spatial Equilibrium Analysis of the United States Dairy Industry with Special Reference to Non-dairy Synthetic Milk.*

David John Standish Rutledge, B.A. University of Sydney, 1965; M.A. Stanford University, 1968; Ph.D. Stanford University, *The Relationship between Prices and Hedging Patterns in the U.S. Soybean Complex.*

Ashok Kumar Singh, B.S. University of Gorakhpur, India, 1961; M.S. Agra University, India, 1964; Ph.D. Oregon State University, *Farm Machinery Merchandising; Farmer and Dealer Preferences Concerning Used Equipment Guarantees, Farm Service Centers and Information Services.*

Lynn Goochey Sleight, B.S. Utah State University, 1948; M.S. University of Illinois, 1950; Ph.D. University of Illinois, *Union Restrictions on Innovations and Their Relationship to Performance in Fluid Milk Delivery.*

Richard William Stammer, B.S. Rutgers University, 1965; M.S. Rutgers University, 1967; Ph.D. University of Connecticut, *A Mathematical Programming Model for Determining the Optimum Spatial Organization of a Multi-Plant Industry, with an Empirical Application to the New England Livestock Feed Processing Industry.*

James Don Tilmon, B.S. University of Missouri, 1965; M.S. University of Delaware, 1967; Ph.D. Purdue University, *An Economic Analysis of the Pork Marketing Channel in Indiana.*

Larry Gene Traub, B.S. South Dakota State University, 1964; M.S. South Dakota State University, 1968; Ph.D. Ohio State University, *Economic Factors Affecting Ohio's Processing Tomato Harvest and Supply.*

Chieh-Hsin Tseng, B.S. Taiwan Provincial Chung-Hsing University, 1958; M.S. Taiwan Provincial Chung-Hsing University, 1961; Ph.D. Ohio State University, *The Consumption and Demand for Soybeans in Taiwan, China.*

Joseph Samson Weiss, B.S. University of San Paulo, 1964; M.S. University of Florida, 1966; Ph.D. Cornell University, *The Benefits of Broader Markets Due to Feeder Roads and Market News: Northeast Brazil.*

Pascal J. Wick, Diploma, Institut d'Etude du Developpement Economique et Social, Paris, 1967; Ph.D. The Pennsylvania State University, *An Interregional Activity Analysis Model of the Pennsylvania Milk Manufacturing Industry.*

Robert Zellner, B.S. University of Florida, 1966; M.S. University of Florida, 1968; Ph.D. University of Missouri, *A Simultaneous Equation Analysis of Selected Terminal Hog Markets.*

XIV. NATURAL RESOURCE ECONOMICS

Solomon Bekure, B.S. Haile Selassie I University, 1963; M.S. Oklahoma State University, 1967; Ph.D. Oklahoma State University, *An Economic Analysis of the Intertemporal Allocation of Ground Water in the Central Ogallala Formation.*

Richard Cleveland Bishop, B.S. Colorado State University, 1965; M.S. Colorado State University, 1967; Ph.D. University of California at Berkeley, *Factors Affecting United States Policy in Ocean Fisheries: A Study in the Political Economy of Resources Management.*

Frank Herbert Bollman, B.Agr.Sci. University of Queensland, 1952; B.Com. University of Melbourne, 1959; Ph.D. University of California at Berkeley, *River Basin Development and the Management of Anadromous Fisheries: An Economic Analysis of the Columbia River Experience.*

Ronald Stephen Boster, B.S. Ohio State University, 1966; M.S. Ohio State University, 1967; Ph.D. University of Arizona, *The Value of Primary Versus Secondary Data in Interindustry Analysis: An Arizona Case Study Emphasizing Water Resources.*

John Douglas Brodie, B.Sc. University of Toronto, 1961; M.A. State College of Forestry; Ph.D. University of California at Berkeley, *Transitional Planning of Forest Management.*

David Y. Chen, B.S. National Taiwan University, 1962; M.S. New Mexico State University, 1966; M.S. University of Wisconsin, 1969; Ph.D. University of Wisconsin, *A Simulated Economic Cost Model for Wisconsin Cottage Resorts.*

Donald John Cocheba, B.S. Southern Illinois University, 1961; M.S. Louisiana State University, 1965; Ph.D. Washington State University, *The Land Market and the Economic Development Process in San Juan County, Washington.*

Michael Henry Cosgrove, B.S. South Dakota State College, 1966; M.S. University of Arizona, 1967; Ph.D. Ohio State University, *Cost and Quality of Water Service in Ohio Cities.*

Leon Ellsworth Danielson, B.S. University of Wisconsin, 1962; M.S. North Carolina State University, 1963; Ph.D. University of California at Berkeley, *Investment in Water Resources with Emphasis on Timing.*

Mohamed Ali Emin El-Saadi, B.S. New Mexico State University, 1965; M.S. New Mexico State University, 1969; Ph.D. University of Illinois,

Evaluation of Investment in Irrigation Under Risk.

Robert R. Fletcher, B.S. University of Wyoming, 1963; M.S. University of Wyoming, 1965; Ph.D. Oklahoma State University, *The Impact of Economic Development of Water Resource Use.*

Eric Bruce Godfrey, B.S. Utah State University, 1967; Ph.D. Oregon State University, *An Economic Evaluation of the Range Improvements Administered by the Bureau of Land Management in the Vale District of Oregon.*

Edward Charles Gray, B.S. University of Queensland, 1955; B. of Economics, University of Queensland, 1961; Ph.D. University of California at Berkeley, *Economic Analysis of the Application of a New Technology: The Utilization of Hot and Saline Groundwater Resources in the Imperial Valley, California.*

Roy Mack Gray, B.S. Texas A&M University; M.S. Texas A&M University; Ph.D. Texas A&M University, *A Study of the Effects of Institutions on the Distribution and Use of Water for Irrigation in the Lower Rio Grande Basin.*

Verne W. House, B.S. University of Wyoming, 1961; M.S. University of Wyoming, 1964; Ph.D. Washington State University, *An Economic Model for Allocation of Multiple-Use Natural Resources.*

Earl Angus Jenson, B.S. University of Alberta, 1963; M.S. Iowa State University, 1968; Ph.D. Iowa State University, *Programming Models of Irrigation Development.*

Waldon R. Kerns, B.S. Virginia Polytechnic Institute and State University, 1962; M.S. Virginia Polytechnic Institute, 1967; Ph.D. The Pennsylvania State University, *Criteria for Determining Economic Priorities in Awarding Sewage Facility Construction Grants.*

Gaines Howard Liner, B.S. North Carolina State University, 1965; M.S. Clemson University, 1968; Ph.D. Clemson University, *Economic Analysis of Water Supply Alternatives in a Multi-County Industrialized Area.*

Garey Banks Perkins, B.S. Auburn University, 1961; M.S. Auburn University, 1963; Ph.D. University of Tennessee, *Estimation of Corn Yield Response to Selected Weather Variables in West Tennessee.*

Marshall Burrell Richardson, A.B. Newberry College, 1965; M.A. Clemson University, 1967; Ph.D. Clemson University, *A Study of the Cost of Waste Water Treatment to Wet Process Textile Plants in South Carolina.*

John Vondruska, B.S. University of California, 1960; M.S. Michigan State University, 1962; Ph.D. Michigan State University, *An Economic Analysis of Small Watershed Project Evaluation Procedures.*

Kenneth Boyd Young, B.S. University of Manitoba, 1961; M.S. University of Manitoba, 1966; Ph.D. University of Montana, *Optimal Use of Ground and Surface Water in the Gallatin Valley, Montana.*

XV. PRODUCTION ECONOMICS AND MANAGEMENT

Vijendra Nath Asopa, B.S. University of Udaipur, 1963; M.S. University of Illinois, 1969; Ph.D. University of Illinois, *An Application of Mathematical Decision Theory to the Economic Evaluation of Water Use in Crop Production.*

Robert Lester Batterham, B.Ag.Econ. University of New England, 1967; M.S. University of Illinois, 1969; Ph.D. University of Illinois, *Investment and Financial Management in Farm Firm Growth.*

Leonard Bauer, B.S. University of Alberta, 1959; M.S. Montana State College, 1965; Ph.D. Oregon State University, *A Quadratic Programming Algorithm for Deriving Efficient Farm Plans in a Risk Setting.*

Sanford Adams Belden, B.S. Purdue University, 1964; M.S. Purdue University, 1967; Ph.D. Purdue University, *An Analysis of Decisions and Performance in a Production and Marketing System for Turkeys.*

Richard Neil Boisvert, B.S. Montana State University, 1966; Ph.D. University of Minnesota, *A Model for Farm Planning Under Uncertain Weather Conditions: An Application to Southern Minnesota Cash Grain Farms.*

Herman Delvo, B.S. North Dakota State University, 1962; M.S. North Dakota State University, 1965; Ph.D. University of Nebraska, *Economic Analysis of Herbicide Use Restrictions on Nebraska Cash-Grain Farms.*

Doyle Alden Eiler, B.S. Purdue University, 1966; Ph.D. Oregon State University, *An Economic Analysis of the Short-Run Demand for Timeliness with Special Reference to Farm Machinery Parts.*

Joaquim Jose de Carmargo Engler, Eng.Agr., Escola Superior de Agricultura Luiz de Queiroz, 1965; Doutor, Agricultural University of Sao Paulo, 1968; M.S. Ohio State University; Ph.D. Ohio State University, *Alternative Enterprise Combinations Under Various Price Policies on Wheat and Cattle Farms in Southern Brazil.*

Melvin Dean Ethridge, B.S. Texas Technical College, 1967; M.S. University of California at Berkeley, 1968; Ph.D. University of California at Berkeley, *California Beef Cattle: An Econometric Analysis.*

Ferenc Fekete, D.Ec.Sc. Hungarian University of Economics, 1958; D.Sc. Hungarian Academy of Sciences, 1968; Ph.D. Iowa State University, *Economics of Cooperative Farming—Objectives and Optima in Hungary.*

Richard L. Gady, B.S. University of Illinois, 1965; M.S. Southern Illinois University, 1966; Ph.D. Purdue University, *An Analysis of the Effect of Inflation, Government Programs and Technology on Farm Firm Growth and Adjustment.*

Lyndon Earl Goodridge, A.A.S. Alfred State Col-

lege, 1960; B.S.A. University of Georgia, 1965; M.S. University of Georgia, 1966; Ph.D. Purdue University, *Evaluation of Information for Agricultural Replacement Decisions.*

Joseph Francis Guinan, B.Agr.Sc. University College, Dublin, Ireland, 1961; M.Agr.Sc. University College, 1964; Ph.D. Iowa State University, *Estimation of Egg Production Functions from Experimental Data with Economic Applications.*

Joel Raymond Hamilton, B.S. University of Wisconsin, 1966; Ph.D. University of California at Berkeley, *Acreage Response: An Econometric Analysis of the Acreage of Selected California Fruit and Nut Crops.*

David Eugene Hansen, B.S. University of California at Davis, 1960; M.S. University of California, Davis, 1961; Ph.D. Iowa State University, *Identification of Economic Impediments to Utilization of Mexico's Idle Lands and Policy Implications for the Ejido and Private Sectors.*

Gerald Alvin Harrison, B.S. University of Illinois, 1965; M.S. University of Illinois, 1966; Ph.D. Iowa State University, *Alternative Statistical Models for Estimation of Acreage Diversion with Farm, County and State Levels of Data: Feed Grain Program (1961–70).*

Gary Dean Harter, B.S. Iowa State University, 1960; M.S. Iowa State University, 1965; Ph.D. Iowa State University, *Estimates of a Dairy Cow Milk Production Function.*

Mario Kaminsky, Diploma, Universidad de Litoria (Argentina), 1960; M.S. University of Wisconsin, 1968; Ph.D. University of Wisconsin, *The Structure of Production of Multiple Output Dairy Farms in the "Centro Santafecino" Region of Argentina: A Multivaried Analysis.*

Paul Kun-Yuan Kau, B.S. National Taiwan University, 1960; M.S. University of Tennessee, 1966; Ph.D. University of Illinois, *A Threshold Model of the Grain Dryer Purchasing Decisions of Illinois Farmers.*

Ronald Duane Kay, B.S. Iowa State University, 1956; Ph.D. Iowa State University, *A Dynamic Linear Programming Model of Farm Firm Growth in North Central Iowa.*

Dong Hi Kim, B.S. Seoul National University, 1953; M.S. Cornell University, 1965; Ph.D. University of Hawaii, *Economics of Fertilizer Use in Production of Food Grains in Korea.*

Lennie G. Kizer, B.S. University of Missouri, 1954; M.S. University of Missouri, 1958; Ph.D. The Pennsylvania State University, *Optimum Farm Organizations with Alternative Housing Systems for Large Pennsylvania Dairy Farms.*

Gary Lentz, B.S. University of Nebraska, 1966; Ph.D. University of Nebraska, *Investment Strategies for Grain-Livestock Farms: A Polyperiod Linear Programming Analysis.*

Chuan-Chian Lim, B.A. National Taiwan University, 1962; M.S. University of Hawaii, 1965; Ph.D. University of Missouri, *An Econometric Investigation of Feed Utilization for Missouri Dairy Farms: A Static Analysis.*

Ashley Lovell, B.S. Tarleton State College, 1967; M.S. University of Missouri, 1970; Ph.D. University of Missouri, *A Feedlot Beef Cattle Production Function Study with an Economic Analysis of Corn-Silage Rations.*

LeRoy Luft, B.S. Montana State University, 1959; M.S. Montana State University, 1967; Ph.D. University of Nebraska, *An Evaluation of Growth Potential for Farmers in South Central Nebraska.*

Bruce Wade Mattox, B.S. University of Tennessee, 1963; Ph.D. Oregon State University, *A Partial Economic Analysis of Hatchery Propagation and Commercial Harvest of Salmonid Resources in Oregon.*

Larry Lynn Nelson, B.S. Southern Illinois University, 1962; M.S. Purdue University, 1964; Ph.D. Purdue University, *Implementation of Large Scale Planning Systems: A Study of Computational Dynamics and Managerial Interface.*

Thomas A. Peterson, B.S.A. University of Alberta, 1950; Ph.D. Washington State University, *An Analysis of Thirteen Years of Commercial Hail Suppression in Central Alberta.*

Winston J. Phillips, B.S. University of the West Indies, 1964; M.S. University of the West Indies, 1967; Ph.D. The Pennsylvania State University, *A Method of Estimating Comparative Returns to Commercial Farm Operator Labor and Management.*

William H. Pietsch, B.S. North Dakota State University, 1966; M.S. North Dakota State University, 1968; Ph.D. Washington State University, *An Input-Output Analysis of Import Substitution: A Case Study of Potential Impacts of Expanded Washington Beef Production.*

Don Pretzer, B.S. Kansas State University, 1955; M.S. Kansas State University, 1970; Ph.D. University of Missouri, *An Analysis of Farm Type Classification Systems.*

Nikolai Pulchritudoff, A.B. Sacramento State College, 1964; M.S. University of California at Davis, 1965; Ph.D. University of California at Davis, *Use of Mitscherlich-Spillman Function to Optimize Economic Returns from Farm Production: The Case of Fertilizer on Campo Cerrado Soils in Brazil.*

Robert Retzlaff, B.S. University of Nebraska, 1966; M.S. University of Nebraska, 1967; Ph.D. University of Missouri, *An Analysis of Cost-Size Relationships in Hog Production.*

Refugio I. Rochin, B.A. University of California, 1966; M.S. University of Arizona, 1967; M.A. Michigan State University, 1969; Ph.D. Michigan State University, *A Micro-Economic Analysis of Smallholder Response to High-Yielding Varieties of Wheat in West Pakistan.*

Paul Eugene Rosenberry, B.S. University of Ne-

braska, 1957; M.S. University of Nebraska, 1958; Ph.D. Iowa State University, *A Proposal for Improving the U.S. Department of Agriculture's Cost and Return Studies.*

Leslie Sheffield, B.S. University of Nebraska, 1950; M.S. University of Nebraska, 1964; Ph.D. University of Nebraska, *Economic Analysis of the Costs and Returns for the Production of Corn Using Center-Pivot Irrigation Systems, Southwest, Nebraska, 1970.*

Bernard Henry Sonntag, B.S.A. University of Saskatchewan, 1962; M.S. University of Saskatchewan, 1965; Ph.D. Purdue University, *Simulated Near-Optimal Growth Paths for Hog-Corn Farms Under Alternative Resource, Price and Efficiency Situations.*

Ignacio Carlos Tandeciarz, Publ. Acct., University of Buenos Aires, 1962; M.S. University of California, 1967; M.A. University of California, 1969; Ph.D. University of California at Berkeley, *Productive Efficiency: A Case Study in the Argentine Agricultural Sector.*

Wayne C. Thomas, B.S. California Polytechnic College, 1965; M.S. University of Nevada, 1967; Ph.D. Washington State University, *Economics of Supplementary Livestock Production in the Columbia Basin of Washington.*

Gayle Steven Willett, B.S. Oregon State University, 1964; M.S. University of Wisconsin, 1966; Ph.D. University of Wisconsin, *Structural Projections of the Wisconsin Dairy Industry's Production Sector to 1980.*

XVI. PUBLIC POLICY AND PROGRAMS

Shirley Collins Browning, B.S. University of Kentucky, 1964; M.S. University of Kentucky, 1967; Ph.D. University of Connecticut, *Analysis of the Optimum Carryover Level for Grains in Relation to Foreign Aid Requirements.*

Alan Barry Carr, B.S. University of Maryland, 1958; M.S. Virginia Polytechnic Institute and State University, 1964; Ph.D. Oklahoma State University, *Comparative Efficiency of Selected Voluntary Control Programs in the Use of Government Funds.*

Thomas E. Dickinson, B.S. University of California, Davis, 1966; Ph.D. Michigan State University, *The Impact of the U.S. Changing Its Tariff on Mexican Winter Tomatoes, 1967–1977.*

Barry Lee Flinchbaugh, B.S. The Pennsylvania State University, 1964; M.S. The Pennsylvania State University, 1967; Ph.D. Purdue University, *The 1968 Voluntary Feed Grain Program: Characteristics of Participation and Intrafarm Cropland Diversion in Indiana.*

Jose Maria Franco, License, University of Santiago, 1951; M.S. University of Wisconsin, 1966; Ph.D. University of Wisconsin, *The Legal Insecurity of Landed Property in Venezuela: A Case Study of the Registry and Cadastral Systems.*

Clark David Garland, B.S. Tennessee Technical University, 1965; M.S. University of Tennessee, 1967; Ph.D. University of Tennessee, *Economic Alternatives and Policy Implications of a Strategic Commodity Reserve for National Security Considerations.*

James R. Horst, B.S. University of Vermont, 1965; M.S. The Pennsylvania State University, 1967; Ph.D. University of Maryland, *An Analysis of the Effects of Alternative Agricultural Support Policies and the Substitution of Ingredients in the Compound Feed Industry of the United Kingdom.*

William Frank Payne, B.S. University of Illinois, 1962; M.S. Southern Illinois University, 1967; Ph.D. Oregon State University, *An Analysis of Japanese Food Grain Policies.*

Wayne R. Ringlien, B.A. Marquette University, 1961; M.A. Georgetown University, 1963; Ph.D. University of Maryland, *Economic Effects of Chilean National Expropriation Policy on the Private Commercial Farm Sector, 1964–69.*

Jorge F. Schuster, B.S. Bradley University, 1954; M.S. University of Wisconsin, 1956; Ph.D. University of Wisconsin, *Rural Problem Solving Policies in Venezuela with Special Reference to the Agrarian Issue.*

Arthur I. Strang, III, B.A. Amherst, 1966; M.S. University of Wisconsin, 1968; Ph.D. University of Wisconsin, *A Regional Relative Productivity Land Tax Proposed by the Government of Bolivia to Replace All Domestic Taxes on Agriculture.*

XVII. REGIONAL ECONOMICS

Gerald Arthur Doeksen, B.S. South Dakota State University, 1965; M.S. Oklahoma State University, 1967; Ph.D. Oklahoma State University, *A Social Accounting System and Simulation Model Projecting Economic Variables and Analyzing the Structure of the Oklahoma Economy.*

Barry Ross Lawson, A.B. Dartmouth College, 1964; M.R.P. Cornell University, 1967; Ph.D. Cornell University, *A Stochastic Model of Settlement on the Urban Fringe: The Role of Land, Its Use, and Related Policy.*

Carlos F. Widmann, B.A. Georgetown University, 1965; M.S. University of Hawaii, 1969; Ph.D. University of Hawaii, *The From-To Interindustry Formulation in Regional Analysis: An Application to an Island Economy.*

XVIII. RESEARCH METHODOLOGY

Milton Hubert Ericksen, B.S. University of Nebraska, 1965; M.S. University of Nebraska, 1966; Ph.D. Kansas State University, *An Analysis of How Kinds and Levels of Specification and Aggregation Detail Affect Accuracy and Usefulness of Recursive Programming Estimates of Production Response.*

William Edward Griffiths, B.Ag.Ec. University of New England, 1967; Ph.D. University of Illinois,

Estimation of Regression Coefficients Which Change Over Time.

Ho Tak Kim, B.S. Seoul National University, 1964; M.S. Seoul National University, 1967; Ph.D. The Pennsylvania State University, *Effects of Aggregation on Errors of Prediction of Macro-Variables.*

XIX. Technological Change

E. Glenn Bowman, B.S. Virginia Polytechnic Institute and State University, 1962; M.S. Virginia Polytechnic Institute, 1968; Ph.D. Virginia Polytechnic Institute, *Teleprocessing Feasibility: An Economic Management Decision Model.*

John G. Ruff, B.S. Fort Hays Kansas State College, 1966; M.A. Kansas State University, 1968; Ph.D. Kansas State University, *Econometric Analysis of the Structural Change of an Agricultural Region: The Case of the Kansas Economy (1954–1967).*

Victor Augustus Whittaker, B.S. A&T College, 1959; M.S. University of California at Berkeley, 1961; Ph.D. University of Illinois, *The Economics of Mechanical Cultivation of Rice Lands in Sierra Leone.*

XX. Miscellaneous

Lawrence Peter Bohl, B.S. Montana State University, 1953; M.S. Purdue University, 1967; Ph.D. Purdue University, *An Analysis of the Behavior of Firms Supplying Purchased Inputs to Agriculture An Experimental Approach.*

Richard Wayne Cartwright, B.S.A. Massey University, New Zealand, 1965; M.S.A. Massey University, 1967; Ph.D. Purdue University, *Research Management in a Department of Agricultural Economics.*

Robert D. Emerson, B.S. Cornell University, 1965; M.A. University of Chicago, 1967; Ph.D. Purdue University, *An Economic Analysis of the Provision of Police Services.*

Thomas Francis Funk, B.S. Purdue University, 1965; M.S. Purdue University, 1968; Ph.D. Purdue University, *Market Analysis of Branded Commercial Feeds.*

Jorge Riestra Matetic, B.S. Catholic University of Chile, 1966; M.S. University of Minnesota, 1969; Ph.D. University of Minnesota, *An Economic Analysis of the Chilean Fresh Fruit and Vegetable Export Sector.*

Aida E. Recto, B.S. University of the Philippines, 1959; M.A. University of Philippines, 1965; Ph.D. University of Minnesota, *An Analysis of the International Demand for Philippine Coconut Products.*

1971 DOCTORAL DEGREE RECIPIENTS BY CONFERRING INSTITUTION

University of Arizona
Ronald Stephen Boster
Arthur Henry Smith

University of California, Berkeley
Richard Cleveland Bishop
Frank Herbert Bollman
John Douglas Brodie
Leon Ellsworth Danielson
Melvin Dean Ethridge
Jeremiah E. Fruin
Edward Charles Gray
Joel Raymond Hamilton
John Horton Humphrey
John George Litschauer
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A Model for Managing Reservoir Water Releases*

Arlo W. Biere and Ivan M. Lee

Two surface reservoirs in California's Salinas Basin are used to increase recharge of valley aquifers. Under the assumptions of zero price elasticity of demand for groundwater, unregulated groundwater withdrawals, and the objective of economic efficiency, the management criterion is to maximize the present value of expected aquifer recharge where the value of a unit of recharge is the associated reduction in pumping costs. A cyclical Markov dynamic programming management model is developed; optimal strategies are obtained. Results indicate the optimal strategy is relatively stable within the realistic range of alternative groundwater demand growth rates. The marginal value function for reservoir capacity is obtained by parametric analysis.

Presented here is a particular model for optimal management of surface reservoir releases to increase water supply. Optimal strategies are developed where the effect of a decision is uncertain but where the set of possible outcomes and the associated probabilities are known. Uncertainty exists because reservoir inflows are not known in advance of the release decisions. Although the inflow which occurs during a period is not known at the beginning of the period, a probability distribution for the set of possible inflows is assumed known. If the year is divided into T periods, the probability distribution would not be expected to be the same for all periods within the year. For example, precipitation expected during a summer month likely will not be the same for a winter month. Consequently, there is an annual cyclical change in the distribution of the stochastic variable. This element is critical to this study since intra-year as well as inter-year aspects of management are considered.

Salinas Basin

Salinas Basin is located in the central coastal region of California. It contains 3,950 square miles of mountain and foothills that serve as a watershed for the 239,000 acres of alluvial and benchlands which are the site of most economic activity. The Basin's major hydrologic features are presented in Figure 1.[1] The Nacimiento, San Antonio, and Arroyo Seco Rivers supply about 75 percent of the valley inflow. As these waters flow over the coarse valley streambeds, water percolates to the aquifers below. The amount which percolates to the aquifers is a function of streamflow, streambed condition, and aquifer storage levels. Percolation efficiency of the valley's natural flows has been low because the natural flows generally are of high intensity for short durations, leaving the valley streambed dry most of the remaining time. From 1929 to 1960 the Salinas River discharged an average of 320,000 acre-feet each year into Monterey Bay, water which might have been used to supplement the community's water supply.

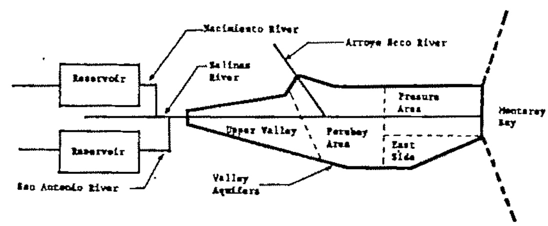

Figure 1. Flow chart of Salinas Basin

Water has been drawn annually from the underground aquifers, primarily for irrigation. As groundwater utilization increased, withdrawals eventually exceeded natural recharge. The result was a declining groundwater table and saltwater intrusion in the aquifers adjoining Monterey Bay. In 1949 the Monterey Flood Control and Water Conservation District was formed to manage the Basin water system. Its purpose was not only to increase water supply but also to provide flood protection and water-based recreation benefits. Since its inception, the District has constructed two surface reservoirs with a combined capacity of 700,000 acre-feet (470,000 acre-feet for water conservation, 200,000 acre-feet for flood con-

* Giannini Foundation Paper No. 344, and Contribution No. 470, Kansas Agricultural Experiment Station. We are indebted to Blair Smith for helpful suggestions. This paper is a revised and condensed version of one phase of analysis first reported in Biere [2].

[1] The flow chart is based on information from the California Department of Water Resources [6] and Ditwiler [7, Ch. 5].

Arlo W. Biere *is assistant agricultural economist at Kansas Agricultural Experiment Station and* Ivan M. Lee *is professor of agricultural economics at the University of California, Berkeley.*

trol, and 30,000 for silt ponds and recreation). One reservoir is located on the Nacimiento and the other on the San Antonio River.

The water conservation function of the reservoir is to impound high intensity flows for release during low streamflows. This extends the time when the valley streambeds are carrying water, which increases percolation. This has significantly increased aquifer productivity in all but two areas. Neither the Pressure area nor the East Side area is a direct recipient of artificial recharge. An impervious blue clay zone over the Pressure area aquifer prevents it from receiving stream recharge, while the East Side aquifer is too far removed from the Salinas River to be a direct beneficiary. Both do receive indirect benefit through lateral groundwater movement. However, this lateral movement is restricted by the resistance of the aquifers. It appears that the eventual solution to the problem in these two areas will be direct delivery of surface water, probably from the existing surface reservoirs.

The Criterion Function

The authors' management criterion is based solely on economic efficiency. The District may provide flood protection, water supply augmentation, and water-based recreation and has allocated the storage capacities of the reservoirs among these uses. For the Nacimiento Reservoir the allocation is fixed by law. This study takes the existing allocations as fixed and considers management strategies associated only with water conservation, the major activity in terms of storage. Accepting the present allocation as a constraint does not imply that it is optimal. A parametric programming analysis bearing on storage allocation is included at the end of this paper.

The only variables under the District's control are the timing and quantity of water releases from the surface reservoirs to percolate to the aquifers. Centrally controlled groundwater withdrawals are not acceptable to the community at this time. Virtually all of the water consumptively used in the study area is drawn from the underground aquifers, and about 95 percent of the groundwater is used for irrigation. Hence, irrigation demand dominates aggregate demand for groundwater. It is assumed that farmers consider irrigation water as a fixed requirement, which leads to a water demand relation with zero price elasticity. Under these conditions, economic efficiency corresponds to aggregate community pumping cost minimization.

The quantitative management model in this study assumes a single surface reservoir. This is permissible because the flows of the Nacimiento and San Antonio Rivers are highly correlated, both entering the Salinas River while it is still in the foothills.[2]

Variable pumping cost per unit of water can be expressed as $(D)*(\text{Lift})$ where D is a constant determined by theoretical energy requirements per foot lift, total plant efficiency, and energy cost.[3] Total plant efficiency is the only factor which can fluctuate with lift. Yet, deep well pumps maintain about the same plant efficiency regardless of lift provided the pump is designed for the lift encountered. It is only when the actual lift differs from the designed lift that the efficiency changes significantly. Unless aquifer storage level fluctuates considerably, D can be expected to remain constant.

Disregarding the dynamics of groundwater movement, storage level of the aquifer uniquely determines lift. If specific yield[4] of the aquifer is a uniform value (m), removal of 1 acre-foot of water will increase lift by the amount $(1/m)$. Let g' be the theoretical storage quantity at which lift is zero. For any aquifer storage level g, lift is $(g'-g)/m$, and cost per acre-foot is

$$b(g) = \frac{g'D}{m} - \frac{D}{m} g = h - \gamma g. \tag{1}$$

The removal of one unit of water (that is, $\Delta g = -1$) increases lift by $1/m$ and cost of pumping the next unit by γ. Electricity is the predominant source of power for pumping in the valley. The marginal rate schedule for electricity decreases in a step function manner as the quantity of electricity purchased increases. This decreasing rate schedule is disregarded and a uniform rate at the lowest step value is assumed. This assumption closely approximates

[2] Monthly correlations were calculated based on 18 years of monthly observations from the U. S. Geological Survey [12]. For the five months of the year accounting for 95 percent of mean annual streamflow (December–April), squared correlation coefficients ranged from .78 to .95. Complete results are reported in Biere [2].

[3] For related technical background discussion, the reader is referred to Israelsen and Hansen [9].

[4] Specific yield is storage capacity per foot depth of aquifer.

the situation in the Salinas Basin.[5] The marginal cost function is, then:

$$MC(s/g) = h - \gamma g + \gamma s \tag{2}$$

where s is quantity pumped. The corresponding total cost is

$$TC(s/g) = (h - \gamma g)s + (\gamma/2)s^2 + a \tag{3}$$

where a represents fixed cost.

Cost relations (2) and (3) are valid for an individual pumper operating in isolation. For a social cost function taking account of the external effect of withdrawing from a common pool, the individual cost curves can be aggregated to form the total community cost function,

$$TC(S/g) = (H - \Gamma g)S + (\Gamma/2)S^2 + A \tag{4}$$

where S is aggregate quantity pumped and H, Γ, and A denote macrocoefficients. The macrocoefficients H and Γ are weighted averages of the corresponding microcoefficients, where the weights are the respective s_i's.

The objective is to time water conservation releases, R, to minimize the present value of the stream of aggregate pumping costs:

$$\begin{aligned} \Lambda &= \sum_{n=1}^{N} \beta^{n-1}[A + (H - \Gamma g_n)S_n + (\Gamma/2)S_n^2] \\ &= \sum_{n=1}^{N} \beta^{n-1}[A + HS_n + (\Gamma/2)S_n^2] \\ &\quad - \sum_{n=1}^{N} \beta^{n-1}\Gamma g_n S_n \\ &= K - \sum_{n=1}^{N} \beta^{n-1}\Gamma g_n S_n. \end{aligned} \tag{5}$$

The first term of (5) does not involve g, level of groundwater storage. Thus, it is not influenced by the recharge policy and can be ignored in the minimization process. Hence, an equivalent criterion is to maximize the negative of the second term,

$$\Lambda' = \sum_{n=1}^{N} \beta^{n-1}\Gamma g_n S_n. \tag{6}$$

The function transforming the groundwater state from period $n-1$ to period n is

$$g_n = g_{n-1} - S_{n-1} + \rho(R_{n-1}) \tag{7}$$

where $\rho(R)$ represents recharge from surface release R. Applying (7) recursively gives

$$g_n = g_o - \sum_{k=0}^{n-1} S_k + \sum_{k=0}^{n-1} \rho(R_k) \qquad \text{for } n = 1, 2, \cdots, N \tag{7.1}$$

where g_o is initial aquifer storage level. Substituting for g in equation (6) gives

$$\Lambda' = \sum_{n=1}^{N} \beta^{n-1}\Gamma S_n \left[g_o - \sum_{k=0}^{n-1} S_k + \sum_{k=0}^{n-1} \rho(R_k) \right]. \tag{8}$$

Since only the last term is influenced by R, it is necessary only to maximize:

$$\begin{aligned} \bar{\Lambda} &= \sum_{n=1}^{N} \beta^{n-1}\Gamma S_n \sum_{k=0}^{n-1} \rho(R_k) \\ &= \Gamma \sum_{k=0}^{N-1} \rho(R_k) \sum_{n=k+1}^{N} \beta^{n-1} S_n \end{aligned} \tag{9}$$

subject to the constraint that surface reservoir releases in any period cannot exceed quantity in storage in that period. This constraint may be written,

$$R_k \leq d + \sum_{n=1}^{k-1} X_n - \sum_{n=1}^{k-1} R_n, \tag{10}$$

where d is initial storage and X_n is reservoir inflow in period n.

With a finite management model for a system expected to operate beyond the planning horizon, a value must be specified for the state of the system at the end of the planning horizon. If no value is attached to water in storage at the end of the process, the optimal plan will call for depleting reservoir storage in calendar period N. This is hardly plausible. One way to avoid this problem is to assume that the system will operate infinitely in the same fashion as in the planning horizon. This approach is adopted

[5] More than 95 percent of irrigation withdrawals fall well into the energy range corresponding to the lowest marginal rate, and the combined range of the higher steps is relatively very short. Reduction in energy requirements associated with the recharge operation would fall far short of that necessary to place the average irrigator on the next higher step of the marginal rate schedule. In these circumstances, taking explicit account of the decreasing rate schedule would complicate considerably the form of this cost function, but would not be expected to affect the subsequently derived optimal recharge policy.

here. The benefit function for the infinite process is

$$(11)\qquad \Lambda^* = \Gamma \sum_{k=0}^{\infty} \rho(R_k) \sum_{n=k+1}^{\infty} \beta^{n-1} S_n.$$

The objective in this study is to examine intra-year as well as inter-year release strategies. This requires that the duration of the basic decision period be less than one year. Since the hydrologic parameters vary with time within the year, it is necessary to divide the year into standard decision periods which occur each year at the same point on the annual cycle. These basic periods within the cycle will be referred to as seasons, with T seasons in each cycle. This is explicitly recognized in the benefit function by changing the time index to a two-variable index in which the first index records the year and the second records the season of the year. Changing the time index, (11) becomes

$$(12)\qquad \Lambda^* = \Gamma \sum_{k=0}^{\infty} \sum_{t=1}^{T} \rho(R_{kt}) \left[\sum_{t'=t}^{T} \eta^{kT+t'-1} S_{kt'} + \sum_{n=k+1}^{\infty} \sum_{t'=1}^{T} \eta^{nT+t'-1} S_{nt'} \right]$$

where η is the seasonal discount factor ($\eta = \sqrt[T]{\beta}$). Factor η^{kT+t-1} from the last two terms in (12),

$$(13)\qquad \begin{aligned} \Lambda^* &= \Gamma \sum_{k=0}^{\infty} \sum_{t=1}^{T} \eta^{kT+t-1} \rho(R_{kt}) \cdot \left\{ \sum_{t'=t}^{T} \eta^{t'-t} S_{kt'} + \sum_{n=k+1}^{\infty} \sum_{t'=1}^{T} \eta^{(n-k)T+t'-t} S_{nt'} \right\} \\ &= \Gamma \sum_{k=0}^{\infty} \sum_{t=1}^{T} \eta^{kT+t-1} \rho(R_{kt}) Z_{kt}. \end{aligned}$$

From (13) it is apparent that Λ^* is the present value of a stream of weighted recharge values. The weights are ΓZ_{kt}. Γ is the reduction in cost per acre-foot resulting from an acre-foot increase in underground storage. Z_{kt} is the discounted sum of aquifer withdrawals from time k, t indefinitely into the future. Consequently, the product ΓZ_{kt} is the present value of the reduction in costs associated with another unit of recharge. The criterion is the present value of the reduction in pumping cost associated with increased aquifer recharge.

Although the release strategy which maximizes (13) can be found with the basic recursive technique of dynamic programming [1], the Howard Improvement Routine [3, 8], when applicable, is more efficient. The Modified Howard Routine [11] requires that the benefit function remain unchanged over years, being a function only of the decision made. In (13) the benefits associated with one of the T periods is $\rho(R_{kt})\Gamma Z_{kt}$. Variable Z_{kt} allows for yearly variations in benefits which are not associated with the decision policy.

Consider the case where the annual withdrawal rate is allowed to grow according to $S_k = \nu^{kT} S$. For a closed solution in the infinite horizon case to exist ν must be such that $0 < \eta\nu < 1$. The special case where annual demand is constant is accommodated by $\nu = 1$. The distribution of withdrawals within each year is assumed to remain fixed; i.e., $S_{kt} = d_t S_k$, where d_t is the proportion of annual withdrawals occurring in period t ($\sum_{t=1}^{T} d_t = 1$). Under these conditions Z_{kt} becomes

$$(14)\qquad \begin{aligned} Z_{kt} &= S \sum_{t'=t}^{T} \nu^{kT} \eta^{t'-t} d_{t'} + S \sum_{n=k+1}^{\infty} \sum_{t'=1}^{T} \nu^{nT} \eta^{(n-k)T+t'-t} d_{t'} \\ &= S\nu^{kT+t-1} \left\{ \nu^{1-t} \eta^{-t} \left[\sum_{t'=t}^{T} \eta^{t'} d_{t'} + \sum_{n=k+1}^{\infty} \delta^{(n-k)T} \sum_{t'=1}^{T} \eta^{t'} d_{t'} \right] \right\} \\ &= S\nu^{kT+t-1} \left\{ \nu^{1-t} \eta^{-t} \left[z_t + z_1 / r' \right] \right\} \\ &= \nu^{kT+t-1} S Z_t' \end{aligned}$$

where $\delta = \nu\eta$ and r' is the annual rate of discount associated with the discount factor δ^T. Substituting (14) into the general criterion function (13) gives

$$(15)\qquad \Lambda^{**} = \sum_{k=0}^{\infty} \sum_{t=1}^{T} \delta^{kT+t-1} S \Gamma Z_t' \rho(R_{kt}).$$

This criterion function is a weighted sum of discounted recharge values, with weights independent of the year of recharge and with discount factor δ instead of η. With growing groundwater demand, δ will be greater than η and more distant future discounted benefits will be increased relative to near future benefits.

Stochastic Management Model

In the previous section it was shown that the optimal strategy is one which releases surface reservoir water to maximize benefit function (13) (or the special function substituting (14) for Z_{kt}). Yet, surface reservoir inflow is unknown; only its probability function is known. Since reservoir inflow is unknown in advance, management involves risk and the objective becomes the maximization of the expected value of the benefit function. If the basic decision period is less than one year in length, it cannot be expected that the stochastic inflow variable will have the same distribution for each t since expected climatic conditions would differ among seasons. Some studies have avoided this problem by regarding a year as the basic decision period [4, 5] when risk is involved. This ignores the question of proper timing of releases within the year.

In solving for the optimal strategy, cyclical Markov dynamic programming which allows the distribution of the stochastic variable to vary in a cyclical manner will be used. The authors' management model has an annual cycle with T decision periods within the cycle. A given decision period within the cycle will always cover the same calendar time period and have the same expected climatic condition.

Two indices, n and t, are required to denote time—t indicating period within cycle and n the year. Let the possible storage levels of the surface reservoir be represented by the discrete index i or j, the decision alternatives be enumerated by the index k, and $q_i^k(t)$ be the expected immediate benefit resulting from decision k in period t when the state of the system is i. Let $p_{ij}^k(t)$ represent the probability that the system in state i and season t will make a transition to state j under decision k, and let $v_i(n, t)$ be the expected discounted return associated with a system starting in state i and period t of year n and operating for an infinite period. A strategy is a complete set of decisions for all states and all periods.

Riis [11] has extended the Howard Improvement Routine to this cyclical case. The Modified Howard Routine finds an optimal stationary policy for an infinite process when the benefit function is stationary over cycles. In this situation the optimal policy is stationary over cycles. Furthermore, any policy used in the first year which increases the expected discounted benefit for the entire period will be an improvement when used for the whole process. Recall that η is a seasonal discount factor such that $\eta^T = \beta$. For a given policy, say k', the discounted total expected benefit may be expressed as

$$(16)\quad v_i(n, t) = q_i^{k'}(t) + \eta \sum_{j=1}^{m} p_{ij}^{k'}(t) v_j(n, t+1) \qquad \text{for } i = 1, \cdots, m.$$

This may be expressed in vector form as

$$(17)\quad V(n, t) = Q(t) + \eta P(t) V(n, t+1).$$

where

$$V(n, t) = (m \times 1) \text{ vector of } v_i(n, t)$$
$$Q(t) = (m \times 1) \text{ vector of } q_i^{k'}(t)$$

and

$P = (m \times m)$ matrix of transition probabilities, where row i is the vector $\{p_{ij}^{k'}, j = 1, 2, \cdots, m\}$.

Note that at time n, T the next period is $n+1$, 1 (that is, at the end of a cycle move to the beginning of the next cycle). Start at $t=1$ and apply recursive equation (17) T times:

$$\begin{aligned} V(n, 1) &= Q(1) + \sum_{t=1}^{T-1} \eta^t \left[\prod_{i=1}^{t} P(i) \right] Q(t+1) \\ (18) \qquad &\quad + \eta^T \left[\prod_{t=1}^{T} P(t) \right] V(n+1, 1) \\ &= W(1) + \eta^T \left[\prod_{t=1}^{T} P(t) \right] V(n+1, 1) \end{aligned}$$

where

$$(19)\quad W(1) = Q(1) + \sum_{t=1}^{T-1} \eta^t \left[\prod_{i=1}^{t} P(i) \right] Q(t+1).$$

$W(1)$ is the expected benefit for the immediate single cycle of T periods. Equation (18) is the expected benefit for the $N-n+1$ cycles remaining in the planning horizon at a given point n. Now, if $0 < \beta = \eta^T < 1$, for $N \to \infty$ and n finite $V(n, t)$ will converge to $V(t)$, as $\lim_{N\to\infty} \beta^N = 0$. Consequently, (18) becomes

$$(20)\quad V(1) = W(1) + \beta \left[\prod_{t=1}^{T} P(t) \right] V(1)$$

and

$$(21)\quad V(1) = \left(1 - \beta \left[\prod_{t=1}^{T} P(t) \right] \right)^{-1} W(1).$$

The state values, $V(1)$, obtained from (21) can be used in the search for an improved policy. The improved policy k^* for $t=T$ is found using the recursive equation,

$$(22)\qquad v_i^*(T) = \operatorname*{Max}_k \left[q_i^k(T) + \eta \sum_{j=1}^{m} p_{ij}^k(T) v_j(1) \right] \quad \text{for } i = 1, \cdots, m.$$

The state values for period T are then used to find the improvement for period $T-1$,

$$(23)\qquad v_i^*(T-1) = \operatorname*{Max}_k \left[q_i^k(T-1) + \eta \sum_{j=1}^{m} p_{ij}^k(T-1) v_j^*(T) \right] \quad \text{for } i = 1, \cdots, m.$$

In like manner the improvement is obtained for the remaining periods of the cycle. If the improved policy differs from the previous one, return to (19) and (21) to calculate the new $V(1)$ and repeat the process. When no further improvement is possible, the policy is optimal.

Empirical Results

In this section the cyclical dynamic programming model is applied to the Salinas Basin. Combining the Nacimiento and San Antonio Rivers to form a single hypothetical stream and surface reservoir is justified by observing that flows in the two streams are highly correlated. The capacity of the hypothetical single reservoir is 480,000 acre-feet, which is nearly equivalent to the combined water conservation storage capacity of the two existing reservoirs. Each year is divided into three decision periods $(T=3)$. The first season covers the interval from August through November; the second, December through March; and the third, April through July. The state of the system is defined by the surface reservoir storage level. Let i be an index representing the state of the system. With 25 state levels, state i represents a storage level of $(i-1)$*20,000 acre-feet. The water release decisions are indexed by k, and the release quantity associated with decision k is $(k-1)$*20,000 acre-feet.

The probability that the system will undergo a transition from state i to state j when decision k is selected in season t is $p_{ij}^k(t)$. At state i, a decision k to release $(k-1)$*20,000 acre-feet will reduce the storage level by this amount. The new state becomes $(i-1)$*20,000 $-(k-1)$*20,000 acre-feet in storage, and the index associated with this state, say i', is $(i-k-1)$. However, during the release there is a non-negative inflow into the reservoir. Hence, the probability that a transition will result in a state less than that denoted by i' is zero, which means that $p_{ij}^k(t)$ equals zero for all $j<i'$. The probability of remaining in state i' is equal to the probability that the inflow is less than 20,000 acre-feet. The probability of moving from state i' to the larger state $i'+i''$ is equal to the probability that the surface inflow to the reservoir is between i''*(20,000) and $(i''+1)$*20,000 acre-feet during the time period. A two-parameter gamma distribution has been fitted to the surface inflow observations for each of the three seasons [2, p. 103]. The inflow probabilities were obtained from the estimated gamma distribution function by referring to tables of the incomplete gamma function.

The benefit function to be maximized is (15), repeated here for convenience replacing subscript k by n,

$$(24)\qquad \Lambda^{**} = \sum_{n=0}^{\infty} \sum_{t=1}^{T} \delta^{nT+t-1} S\Gamma Z_t' \rho(R_{nt}).$$

The benefit associated with the decision in year n and season t is $S\Gamma Z_t'\rho(R_{nt})$. In the stochastic model the decision uniquely specifies the amount of water released during the period. The recharge resulting from the release depends upon the climatic conditions during the release period, since the flow of the Arroyo Seco River, another tributary of the Salinas River, is uncontrolled. The flow of the Salinas River which may percolate in period t consists of surface releases, R_t, and natural flow of the Arroyo Seco, U_t. Since U_t is a stochastic variable, the sum R_t+U_t is also stochastic. The streamflow percolation relationship was estimated by a quadratic regression [2, p. 105]. It can be shown [2, p. 109] that the expected additional recharge resulting from the surface release R_t is of the form

$$E[\rho_t(R_t; U_t)] = a_{1t}R_t + a_2 R_t^2.$$

Then, the expected immediate benefit associated with release R_{nt} is

$$S\Gamma Z_t'[a_{1t}R_t + a_2 R_t^2].$$

$q_i^k(t)$ is the immediate benefit expected from decision k in period t at state i. In this model the state of the system constrains the feasible set of decisions (i.e., $k \leq i$; release $\leq$ storage) but does not affect the immediate expected benefit associated with a decision. Thus, the state subscript may be dropped. Since decision k implies the release of $(k-1)$*20,000 acre-feet of water, the expected immediate benefit associated with decision k is

$$q^k(t) = S\Gamma Z_t'[a_{1t}(k-1)^*20{,}000 + a_2\{(k-1)^*20{,}000\}^2]. \tag{25}$$

Ditwiler [7] estimated annual withdrawals in 1963 at 434,860 acre-feet. This estimate is used for S in equation (25). Γ represents the change in pumping cost associated with a unit change in reservoir storage. The District has estimated that storage per foot depth of aquifer is 20,000 acre-feet; therefore, the change in lift associated with a change of 1 acre-foot in storage level is (1/20,000) feet. The average change in variable pumping cost associated with a one-foot change in lift is \$.061 per acre-foot. This estimate was obtained by averaging the cost per acre-foot per foot lift for the relevant areas as given by Snyder and Moore [10]. Γ is the product of these two values, giving $\Gamma = \$3.05 \times 10^{-6}$.

Projecting a rate of growth for groundwater withdrawals is subject to considerable uncertainty. Planning for the Salinas Valley has stressed maintaining irrigated agriculture and the related agricultural processing industry as the dominant component of the Valley's economy. The potential for growth in irrigated acreage exists but the extent and rate of growth is more conjectural [7].[6] To determine an empirical basis for deriving a value for ν, data on growth in irrigated acreage in the Valley from 1954 to 1964 has been used. The resulting value for ν is 1.004947 which implies an annual rate of growth in groundwater withdrawals of about 1.5 percent.

In the past the District has used a 4 percent annual discount rate. The authors have adopted this same rate in their analysis. With a 4 percent annual discount rate the annual discount factor, β, is .9615 and the seasonal discount factor, η, is .9865. This results in a δ of .9914 and an adjusted annual discount rate, r', corresponding to the annual discount factor δ^3, of 2.63 percent.

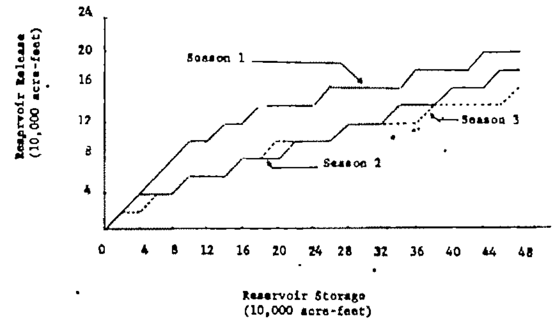

Figure 2. Optimal strategy—exponentially increasing demand

Recall from equation (14) that

$$Z_t' = \nu^{1-t}\eta^{-t}[z_t + z_1/r']$$

where

$$z_t = \sum_{t'=t}^{T} \eta^{t'} d_{t'}.$$

Approximately one-half of the total annual withdrawals occur in each of season 1 and season 3 with practically no withdrawals in season 2. Hence, $d_1 = d_3 = .5$ and $d_2 = 0$. The computed values for Z_t' are $Z_1' = 38.528$, $Z_2' = 38.359$, and $Z_3' = 38.693$. Empirical values of coefficients in the expected recharge function are: $a_{11} = 1.04113$; $a_{12} = .81981$, $a_{13} = .98992$, and $a_2 = -1.2628 \times 10^{-6}$.

A graphical summary of the optimal policy is presented in Figure 2. Quantity released is presented as a function of storage quantity in each season. For all three seasons the release functions rise rapidly at the beginning and then flatten out. In season 1 all water in storage is released for all state levels from zero to 100,000 acre-feet. Since percolation efficiency decreases as streamflow increases, much of the water at the higher storage levels is held over for possible use in seasons following low inflows, when it can be used more efficiently. The cost of holding the water is the value of the possible inflow which may be lost because storage space used to hold this water is not available to capture new inflows.

While examining the optimal policy, recall

[6] Of course, if irrigation withdrawals are maintained, there will be some demand growth due to growth in withdrawals for nonagricultural uses. This growth is accommodated by our model if one assumes that water demand in each of these uses has a price elasticity of zero over the relevant price range. However, in view of the very minor share of groundwater presently going to nonagricultural uses (about 5 percent), a very substantial rate of growth in these uses would be required to have much effect on ν.

that inflow into the percolation area from the Arroyo Seco River affects the percolation efficiency of water released from the reservoir. If flow from the Arroyo Seco is high, the additional percolation from water released will be less than when flow is low. The mean flow of the Arroyo Seco is highest in season 2. Therefore, the lowest expected percolation efficiency for water released from the reservoir is in season 2. Expected efficiency for each of the remaining two seasons is much higher, with season 1 slightly above season 3. The results shown in Figure 2 may not seem reasonable at first glance because the release function for season 3 is below that for season 2, while the expected percolation efficiency for season 3 is above that for season 2. This can be explained by the fact that little or no inflow is expected in season 3 and the water must be rationed between seasons 1 and 3.

The optimal policy can be better understood by tracing the management policy for three illustrative situations (denoted as Cases 1, 2, and 3 below). Although the annual cycle nearly coincides with the water year defined by the District, season 3 is selected as the starting point in the examples below. That is, in these examples the order of seasons is 3, 1, 2. Season 3, which immediately follows the season in which 80 percent of the inflow occurs, is selected as the starting point because it provides greater insight into how the policy operates. Even if the reservoir were empty at the beginning of season 2, it would be possible for inflow to move the system to any of the possible states by the end of season 2. The probability that inflow will be greater than 100,000 acre-feet is .76; greater than 180,000 acre-feet, .51; and greater than 320,000 acre-feet, .25. Inflow expected in season 3 is very low. In these examples only the possibilities of no flow or a flow of 20,000 acre-feet are considered, since the probability that one of these events occurs is about two-thirds. For season 1 the probability of no inflow is .94; therefore, only the case of no inflow is considered.

Case 1

If storage in the reservoir at the beginning of season 3 is 100,000 acre-feet, 60,000 acre-feet would be released for percolation purposes during season 3. During season 3 inflow is either zero or 20,000 acre-feet according to the assumptions above. Accordingly, storage level at the end of season 3 is either 40,000 or 60,000 acre-feet. For either of these states the policy for season 1 is to release all of the water in storage. With no inflow into the reservoir during season 1, no water will be available for release in season 2. Also, no water will be held over for the next year.

Case 2

If storage at the beginning of season 3 is 200,000 acre-feet and assumptions regarding inflow are the same as above, release in season 3 is 100,000 acre-feet. With an inflow of either zero or 20,000 acre-feet, storage level at the end of season 3 is either 100,000 or 120,000 acre-feet. With storage at either 100,000 or 120,000 acre-feet, the release is 100,000 acre-feet in season 1. With no inflow during this season storage at the end of season 1 is either 0 or 20,000 acre-feet. The 20,000 acre-feet would be released in season 2. No water is held over for the next year.

Case 3

If storage at the beginning of season 3 is 400,000 acre-feet, the decision in season 3 is to release 140,000 acre-feet. At the end of season 3 the storage level is either 260,000 or 280,000 acre-feet. The decision in season 1 is to release 160,000 acre-feet. Assuming no inflow during season 1, storage level at the end of the season is either 100,000 or 120,000 acre-feet, and the decision for season 2 is to release 60,000 acre-feet. The remaining 40,000 or 60,000 acre-feet will be held over to the next year.

Note in these examples that the initial storage levels selected cover the range of possible levels at the end of season 2. The two alternative inflows assumed for season 3 account for 66 percent of the probable inflows; the assumption of no inflow during season 1 accounts for 94 percent of the probable flows. Consequently, it can be concluded that these examples present realistic indications of the effects of this policy. Conclusions that may be drawn are: (1) only if the reservoir is very near capacity at the end of season 2 is it likely that some water will be held over to the next year, and (2) most of the water will be released during seasons 3 and 1. In other words, inter-year storage is likely to be very small, the major purpose of the reservoir being to change the pattern of flows within the year. Only when the reservoir is nearly half full at the beginning

of season 3 is it likely that water will be released in the following winter months, season 2.[7]

Allocation of reservoir storage

Optimal release policies have been derived for the existing fixed allocation of storage to water conservation (470,000 acre-feet), accepting the existing fixed allocations of remaining storage to flood control and recreation. However, in most actual situations the proper allocation of storage space is an important issue. The management model is well suited for examining the relationship between water conservation efficiency benefits and storage allocations. The opportunity cost of water conservation storage can be deduced from this relationship. Given suitable data to permit measurement of the relationship between efficiency benefits and storage allocations to other uses, the optimal allocation of storage capacity can be derived.[8] The analysis which follows relates only to the allocation of storage between conservation and flood control. In view of the rather crude measures of flood benefits used, the results should be regarded as mainly illustrative in character.

To generate the relationship between capacity and conservation benefits, the first step is to find an optimal policy for the largest conservation storage capacity. The computer program can be easily altered to reduce the conservation storage by adjusting the transition probabilities. Then, using the optimal policy for the previous capacity as an initial solution, the optimal policy corresponding to the reduced conservation capacity can be found. This procedure can be repeated over the desired range of conservation allocations. In the results generated here, the allocation was varied in 20,000 acre-feet increments from 580,000 acre-feet to 100,000 acre-feet. The annual discount rate was set at 4 percent and withdrawal demand was assumed constant (i.e., $\nu=1$).

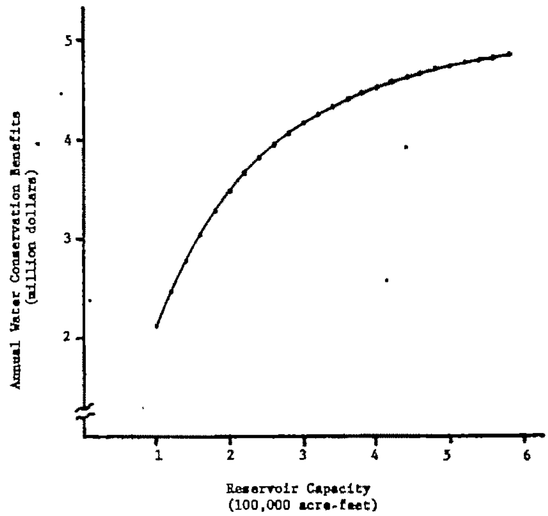

Figure 3. Water conservation benefit function for surface reservoir

For the optimal policy $v_1(1)$ is the present value of expected benefits if the system starts in state 1, season 1 and operates indefinitely under the optimal policy. Since management is generally confined to some finite horizon, it is helpful to evaluate benefits on an average annual basis. The expected average annual benefit is $(r/1+r)v_1(1)$. It is sufficient to evaluate the criterion at only one state value since the difference between two state criterion values is only the immediate advantage or disadvantage of starting in one state instead of another.

The average annual expected benefits are shown on Figure 3. Note the operation of the law of diminishing returns, which can be seen more easily by observing the marginal benefit function in Figure 4. At 120,000 acre-feet of storage the annual marginal benefit associated with an additional unit of storage is $17.70, whereas at 580,000 acre-feet of storage the annual marginal benefit is $1.15. This curve depicts the schedule of opportunity costs incurred as storage is diverted away from water conservation to some alternative use.

The specific alternative use considered here

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[7] The 1.5 percent growth rate in withdrawals may be regarded as too generous. Results were also generated using a zero withdrawal growth rate (i.e., for $\nu=1$). Comparison of the zero-growth results with those in Figure 2 illustrates the relative insensitivity of optimal water release policy to growth of water demand within a range which may be regarded as including a more realistic growth rate. The zero-growth policy differs from the policy depicted in Figure 2 at only three state values, and in each instance the difference in release is only 20,000 acre-feet. In season 1 at a storage level of 340,000 acre-feet the zero-growth policy indicates a release of 180,000 acre-feet, compared with 160,000 acre-feet under the policy in Figure 2. In season 3 a release of 120,000 acre-feet, instead of 100,000 acre-feet, is indicated with storage at 260,000 acre-feet; and a release of 140,000 acre-feet, instead of 120,000 acre-feet, is indicated at 360,000 acre-feet in storage.

[8] We assume that economic efficiency is the sole criterion for storage allocation. In most situations factors other than economic efficiency (resulting, perhaps, in extra weight being given to flood benefits and/or water-based recreation) may be important in determining the proper allocation.

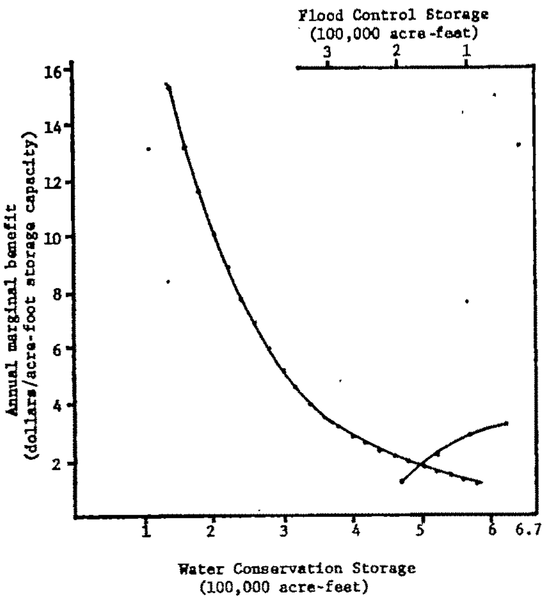

Figure 4. Annual marginal benefit of storage space

is flood control, with a present fixed allocation of 200,000 acre-feet. No data are available on flood control benefits expected from the combined operation of the two reservoirs. However, a 1955 report [6, p. 94] estimated flood control benefits for a reservoir near San Lucas. The estimated average annual flood control benefits were $180,000, $322,000, and $398,000 at flood storage capacities of 50,000, 100,000, and 150,000 acre-feet, respectively. Since the San Lucas site would intercept flows from both streams, it would be more effective in preventing flood damage than the two dams presently operating in parallel. To allow for this, it is assumed that one-third more combined storage would be necessary to provide the level of flood protection provided by the San Lucas Reservoir. In addition, the flood benefits are adjusted for general price changes between 1955 and 1964 to make flood control benefits comparable with the authors' water conservation benefits.

The marginal benefit functions intersect at a water conservation allocation of 500,000 acre-feet, compared with an actual conservation allocation of 470,000 acre-feet. There is need for more accurate flood benefit data before one can draw a firm conclusion on the optimal allocation. Assuming that flood benefits are correctly estimated, a strict interpretation of these results suggests that either noneconomic factors not accounted for in this approximation enter the flood control benefit measures used by the District or too much is being allocated to flood control at the expense of water conservation.

A similar analysis could be used to appraise the present allocation of storage to water recreation. However, good information on recreation benefits is not available. An alternative procedure might be to constrain the release strategy to meet some predesignated recreation objective and to measure the water conservation benefits foregone to meet this objective. This would give an indication of the minimal amount of recreation benefits necessary to justify the allocation to recreation on an economic basis.

Summary

A quantitative management model is developed for deriving optimal temporal conservation water release strategies for two existing reservoirs in the Salinas Basin. Certain simplifying assumptions and procedures are adopted. First, due to the high correlation between inflows, the two reservoirs are treated as a single reservoir with a total capacity equal to the combined capacity. Second, it is assumed that the demand for groundwater is price inelastic over the relevant price (pumping cost) range. Virtually all water consumptively used in the Valley is drawn from the aquifers and most of the water is used for irrigation. Hence, irrigation demand dominates aggregate demand, and at the present low cost of pumping an assumed price elasticity of zero can be considered a close approximation. Third, uncontrolled pumping is assumed, recognizing the fact that the public water agency cannot at the present time control aggregate groundwater withdrawal.

The only objective considered in the model is economic efficiency. Moreover, existing fixed flood control and recreation storage allocations are accepted as constraints. Optimal conservation water release strategies are derived for two situations—one which makes generous allowance for growth in annual water demand and one which assumes annual water demand is constant. There were only minor differences in the resulting strategies.[9]

[9] Optimum strategies for a restrictive form of conjunctive use which allows for supplying surface water to the Pressure and East Side areas have been obtained in the larger study on which this paper is based [2]. However, the required surface facilities do not now exist to implement conjunctive use. Present conservation releases are entirely for groundwater recharge. Due to space considerations we have limited treatment in this paper to models dealing with release policy appropriate to presently existing facilities in the Basin.

Finally, although the release strategies derived accept the existing fixed allocation of reservoir capacity to different uses as a constraint, illustrative results are developed bearing on the optimal allocation of capacity to conservation and flood control.

References

[1] BELLMAN, RICHARD, *Dynamic Programming*, Princeton, Princeton University Press, 1957.

[2] BIERE, ARLO W., "Economics of River Basin Management with Special Reference to the Salinas Basin," unpublished Ph.D. thesis, University of California, Berkeley, 1968.

[3] BLACKWELL, DAVID, "Discrete Dynamic Programming," *Annals Math. Stat.* 33:719–726, June 1962.

[4] BURAS, NATHAN, "Conjunctive Operation of Dams and Aquifers," *J. Hydraulics Division*, Proceedings of the American Society of Civil Engineers, 89:111–131, Nov. 1963.

[5] BURT, OSCAR R., "The Economics of Conjunctive Use of Ground and Surface Water," *Hilgardia* 36:31–111, Dec. 1964.

[6] California, Department of Water Resources, Water Resources Board, *Salinas River Investigation*, unpublished bulletin, 1955.

[7] DITWILER, CORTLANDT D., "The Political Economy of Water Use and Integrated Water Resource Management in the Salinas Valley, California," unpublished Ph.D. thesis, University of California, Berkeley, 1966.

[8] HOWARD, RONALD A., *Dynamic Programming and Markov Processes*, Cambridge, The M.I.T. Press, 1960.

[9] ISRAELSEN, ORSON W., AND VAUGHN E. HANSEN, *Irrigation Principles and Practices*, 3rd ed., New York, John Wiley and Sons, Inc., 1962.

[10] MOORE, C. V., AND J. H. SNYDER, "Pump Irrigation: Cost Increases in Salinas Valley," *Calif. Agr.* 19:14–15, Aug. 1965.

[11] RIIS, J. O., "Discounted Markov Programming in a Periodic Process," *Oper. Res.* 13:920–929, Nov.-Dec. 1965.

[12] U. S. Geological Survey, *Surface Water Supply Papers*, various dates.

Estimation of Demand Parameters Under Consumer Budgeting: An Application to Argentina*

A. DE JANVRY, J. BIERI, AND A. NUÑEZ

This study assumes that consumer expenditures occur in a stepwise fashion in which income is first allocated to budget categories and then to optimum quantities within each category. With this assumption, a model was developed to estimate the price and income elasticities of demand of all items in one budget category—like food—and the cross-price elasticities of these items with all others. The approach permits one to specify the changes in expenditure levels on budget categories from cross-section information and the flexibility of money. The model was empirically applied to Argentine consumption data.

SEVERE LIMITATIONS to the use of the classical theory of consumer behavior as a basis for empirical analysis stem from the large number of parameters contained in demand equations, from the difficulty of defining quantities for many categories of expenditures, from the general lack of time-series data, and from the existence of multicollinearity among price series. Restricting the classical model to one where stepwise decision making occurs by preliminary budgeting over categories of items, as in Strotz [36] and Gorman [24], provides a means of alleviating these limitations and of partially bridging the gap between theory and empirical analysis. The purpose of this paper is to show how this restricted model of consumer behavior with budgeting of expenditures can be used for empirical analysis. In this formulation, cross-section data alone permit the measurement of changes in the expenditure levels on major categories of items in response to changes in the prices of specific goods. Time-series data for commodities belonging to one budget category—food, for example—also permit estimation of the price and income elasticities of the commodities in this category. The model is applied to Argentine consumption data.

The Model

Consider, for simplification, only one time period and assume that the consumer, in his search for a maximum of utility under a budget constraint, budgets his income m over S categories of expenditures ($R=I, \cdots, S$). In the first stage of this optimization process, expenditure functions of the following type are obtained:

$$m_R = m_R(P_I, \cdots, P_S, m) \tag{1}$$

where m_R is the expenditure on group R of commodities and where $P_I, \cdots, P_S$ are price indexes[1] for each budget category of the form

$$P_R = P_R(p_{R1}, \cdots, p_{Rn_R}).$$

The $p_{R1}, \cdots, p_{Rn_R}$ are the prices of the n_R goods which constitute group R. This budgeting is made under the income constraint $\sum_R m_R = m$.

The second stage of the optimization process consists of the determination of the quantity demanded of each item $r \epsilon R$ under the expenditure constraint $\sum_{r \epsilon R} p_r q_r = m_R$. These quantities are determined in the second-stage equations,

$$q_r = q_r(p_{R1}, \cdots, p_{Rn_R}, m_R), \qquad r \epsilon R. \tag{2}$$

The demand equations in this budgeting process are, hence, the two-stage demand equations,

$$q_r = q_r[p_{R1}, \cdots, p_{Rn_R}; m_R(P_I, \cdots, P_S, m)], \qquad r \epsilon R.$$

The corresponding two-stage price and income slopes are

$$\frac{\partial q_r}{\partial p_{r'}} = \left(\frac{\partial q_r}{\partial p_{r'}}\right)_{m_R} + \frac{\partial q_r}{\partial m_R}\frac{\partial m_R}{\partial P_R}\frac{\partial P_R}{\partial p_{r'}}, \qquad r, r' \epsilon R;$$

$$\frac{\partial q_r}{\partial p_k} = \frac{\partial q_r}{\partial m_R}\frac{\partial m_R}{\partial P_K}\frac{\partial P_K}{\partial p_k}, \quad r \epsilon R, \qquad k \epsilon K \neq R;$$

$$\frac{\partial q_r}{\partial m} = \frac{\partial q_r}{\partial m_R}\frac{\partial m_R}{\partial m}, \quad r \epsilon R.$$

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A. DE JANVRY *and* J. BIERI *are assistant professors of agricultural economics at the University of California, Berkeley.* A. NUÑEZ *is professor of economics at the Catholic University, Buenos Aires.*

[1] Existence of these price indexes will be discussed later.

The symbol $(\ )_{m_R}$ indicates that m_R has been held constant in the process of differentiation.

Under strong separability of the utility function, Gorman [24] has proved the existence of local group price indexes of the form,

$$dP_R^* = \sum_{r \in R} a_r dp_r, \; a_r = a_r(p_1, \cdots, p_n, m), \quad R = 1, \cdots, S,$$

on the basis of which consistent local adjustments in demand can be performed through two-stage maximization.[2] Strong separability implies that the Slutsky substitution terms between items in different groups are of the form $K_{rk} = \theta(\partial q_r/\partial m)(\partial q_k/\partial m)$, $r \in R$, $k \in K \neq R$, where θ is a factor of proportionality that is a function of prices and income [23]. de Janvry and Bieri [16] have shown that the functional form of these local group price indexes is

$$(3) \qquad dP_R = \sum_r \left(\theta \frac{\partial q_r}{\partial m} - q_r\right) dp_r$$

and that the corresponding first-stage expenditure functions (equation 1), in differential form, are

$$(4) \qquad \begin{aligned} dm_R = &- \left(1 - \frac{\partial m_R}{\partial m}\right) dP_R \\ &+ \frac{\partial m_R}{\partial m}\left(\sum_{K \neq R} dP_K + dm\right). \end{aligned}$$

Using the functional form obtained for the group price indexes, the two-stage price and income slopes become

$$\frac{\partial q_r}{\partial p_{r'}} = \left(\frac{\partial q_r}{\partial p_{r'}}\right)_{m_R} + \frac{\partial q_r}{\partial m_R}\left(1 - \frac{\partial m_R}{\partial m}\right)\left(q_{r'} - \theta \frac{\partial q_{r'}}{\partial m}\right), \quad r, r' \in R;$$

$$\frac{\partial q_r}{\partial p_k} = - \frac{\partial q_r}{\partial m_R} \frac{\partial m_R}{\partial m}\left(q_k - \theta \frac{\partial q_k}{\partial m}\right), \quad r \in R, \; k \in K \neq R;$$

$$\frac{\partial q_r}{\partial m} = \frac{\partial q_r}{\partial m_R} \frac{\partial m_R}{\partial m}.$$

[2] Here, consistent maximization means that the same equilibrium quantities and, thus, group expenditure levels are obtained with both direct and stepwise maximization of the utility function. Local consistency means that adjustments around one equilibrium point in response to small changes in prices and income are identical whether determined through direct or two-stage maximization.

Under the assumption of block additivity,[3] $\theta = -m/\check{\omega}$ where $\check{\omega}$ is the elasticity of the marginal utility of income with respect to income, named by Frisch [19] "money flexibility." The two-stage price (E) and income (η) elasticities are then,

$$(5) \qquad E_{rr'} = (E_{rr'})_{m_R} + w_{r'}\eta_{r/R}\left(\frac{m}{m_R} - \eta_R\right) \cdot \left(1 + \frac{1}{\check{\omega}} \eta_{r'/R}\eta_R\right), \quad r, r' \in R,$$

$$(6) \qquad E_{rk} = - w_k \eta_{r/R}\eta_R \left(1 + \frac{1}{\check{\omega}} \eta_{k/K}\eta_K\right), \quad r \in R, \; k \in K \neq R,$$

and

$$(7) \qquad \eta_r = \eta_{r/R}\eta_R$$

where

$$w_r = p_r q_r / m, \quad \text{the budget shares,}$$

and

$$\eta_R = \frac{\partial m_R}{\partial m} \frac{m}{m_R},$$

$$\eta_{r/R} = \frac{\partial q_r}{\partial m_R} \frac{m_R}{q_r}.$$

Quantification of the price and income elasticities requires the estimation of three sets of parameters:

1. $\check{\omega}$: It is obtained from the knowledge of the price and income elasticities for one additively separable group or can be predicted as a function of prices and income as in the next section.
2. η_R, η_K; $\eta_{k/K}$: They are obtained from the fit of Engel functions using cross-section consumer expenditure surveys.
3. $(E_{rr'})_{m_R}$, $\eta_{r/R}$: They are obtained from the fit of the second-stage demand equations (2) using only time-series data for the items entering budget category R. Noting that equations (2) are block recursive with respect to the first-stage expenditure functions (1) and assuming that the error terms in (1) are not transmitted to (2), equations (2) can be estimated by ordinary least squares from observed data.[4]

[3] This is the cardinal version of strong separability. Use of cardinality allows measuring θ from the estimation of $\check{\omega}$ as in the second section.

[4] The reasoning here is as follows: Since m_R is determined in a first-stage maximization, it is predetermined with

Presently, available domestic consumption data for Argentina consist of yearly aggregate time series for major types of raw food products elaborated on the basis of production and international trade data for the period 1938–1967 [30] and of one countrywide budget survey made in 1963 [13]. An estimate of the money flexibility for Argentina is derived; then the coefficients of the group expenditure functions are obtained; and, finally, the second-stage and two-stage price and income elasticities of demand for food products are determined.

Estimation of the Flexibility of Money Schedule

In order to estimate the price elasticities in equations (5) and (6), $\breve{\omega}$ is needed. Since $\breve{\omega} = (\partial\lambda/\partial m)/(m/\lambda)$, where λ is the marginal utility of income which is a function of prices and income, $\breve{\omega}$ is a function homogeneous of degree zero in prices and income. In equations (5) and (6), the predicted value of $\breve{\omega}$ that corresponds to the price and income levels at which the elasticities are being measured must be used. To do so, the flexibility of money schedule that relates $\breve{\omega}$ to p and m needs to be determined empirically. According to Frisch [19, p. 189], this schedule should increase from large negative values to small negative values as the level of real income increases.

If it is assumed that food is additively separable from all other items in the consumer's budget, measurements of $\breve{\omega}$ can be obtained from prior estimates of the price and income elasticities of food. Following Frisch [19, p. 187], the money flexibility is then obtained from

$$\breve{\omega} = \frac{\eta_i(1 - w_i\eta_i)}{E_{ii} + w_i\eta_i}. \tag{8}$$

Searching exhaustively in the literature, 26 measurements were compiled of E_{ii} and η_i for food obtained over different time intervals and in different countries in the following studies: for the *United States*, Waugh [43], Brandow [7], Burk [8, p. 297; 9], Tweeten [41], Girshick and Haavelmo [21], Tobin [39], Cochrane and Lampe [12], Chetty [11], Fox [18], Suits and Sparks [37], Tolley, Wang, and Fletcher [40, p. 696], and Booth and Judge [5, p. 560]; for *Norway*, Johansen [27, p. 107] and Amundsen [1, pp. 131–169]; for *Argentina*, de Janvry [15, p. 39] and Barreiros, Fucaraccio, and Herschel [2]; for *Peru*, La Molina Universidad Agraria [28, p. 65]; and for *Israel*, Mundlak [29, p. 78]. Using the average budget share over the interval of observation in each study, point estimates of $\breve{\omega}$ are obtained from equation (8); $\breve{\omega}$ is then regressed on the average level of per capita income m/P observed in the sampling interval of each study. Per capita disposable income in United States dollars is m, and P is the cost-of-living index in the United States [42, p. 503]. The flexibility of money schedule obtained in this fashion is

$$\log_e(-\breve{\omega}) = \underset{(5.01)}{1.5910} - \underset{(-3.91)}{.5205}\log_e\frac{m}{P} \tag{9}$$

$$R^2 = .39 \quad F = 15.25.$$

This schedule is statistically significant and consistent with Frisch's conjecture.

The flexibility of money can also be obtained directly from estimation of the parameters of cardinal utility functions and from the estimation of systems of demand equations where the assumption of additivity is made. Again surveying the literature exhaustively, 24 estimates of $\breve{\omega}$ were obtained with the linear expenditure system by Stone [35, p. 518] for the United Kingdom and by Goldberger and Gamaletsos [22, p. 43] for Canada, the United States, Denmark, Greece, Ireland, Italy, Luxembourg, and Norway. Estimates were also obtained by Houthakker and Taylor [26, pp. 228–229] with a quadratic utility function for the Netherlands, Canada, the United States, and Sweden.

respect to q_r; and the system of first- and second-stage demand equations is *block recursive* with one block composed of the first-stage expenditure equations and another of the second-stage demand equations. If we assume that random disturbances are introduced in these equations to account for errors in maximizing, the variance-covariance matrix of residuals will be block diagonal since maximization is performed in two separate stages. Thus, the second-stage demand equations can be fitted independently of the first-stage expenditure functions. Further, second-stage maximization takes place separately in each budget category so that errors in maximizing cannot be transmitted from one group to another. The variance-covariance matrix of the system of second-stage demand equations is also block diagonal, and each of the S systems of equations can be fitted separately. Within each of these systems, all the exogenous variables are the same—namely, $p_{R1}, \cdots, p_{Rn_R}, m_R$—so that, following Zellner [44], consistent and efficient estimates can be derived from least-squares equation-by-equation fits.

Using the restrictions imposed by pointwise additivity in the estimation of demand functions, further measurements of $\check{\omega}$ were obtained: for the *Netherlands*, Barten [4, p. 241] and Theil [38, p. 238]; for the *United Kingdom*, Pearce [31, p. 507]; for *Australia*, Gruen and others [25, p. 55] and Powell [33, p. 674]; for *Canada*, Powell [32, p. 565]; and for *Chile*, Dillon and Powell [17]. Finally, $\check{\omega}$ was also estimated for the Netherlands by Barten [3, p. 22] and for the United States by Boutwell and Simmons [6, p. 376], using the restrictions of block-additivity in the estimation of systems of demand equations.

To determine the flexibility of money schedule, these measures of $\check{\omega}$ are regressed on the average level of real income in the sampling interval of each study:

$$(10)\quad \log_e(-\check{\omega}) = \underset{(3.92)}{1.7595} - \underset{(-2.42)}{.5127} \log_e \frac{m}{P}$$

$$R^2 = .21 \quad F = 5.86.$$

The fit is statistically significant and, indeed, highly consistent with the schedule obtained from the indirect measurements of $\check{\omega}$.

In a later section, the two-stage elasticities of demand in Argentina are measured for the period 1960–1963. A prediction of $\check{\omega}$ for this period is therefore needed. For these years, $m = \$493$ (U. S.) and $P = 104.9$ which gives a predicted $\check{\omega}$ of -2.2 from the flexibility of money schedule equation (9) and of -2.6 from equation (10). A value of $\check{\omega}$ of -2.5 is used.[5]

Estimation of Expenditure Functions for Major Categories of Items

Frisch's scheme [19] for estimating all price and income elasticities for the *quantities* demanded of major categories of items based on the assumption of pointwise additivity has been used frequently in the literature. The method is appropriate if group quantity indexes *exist*. This is the case only if Hicks' theorem on composite goods is satisfied within each separable group or if the separable subfunctions in the utility function are homogeneous of degree one. It can be seen as follows.

If Hicks' theorem on composite goods is satisfied within each budget category, the prices of all items within a same group vary proportionately, that is,

$$(11)\qquad dp_{Rr} = \frac{p_{Rr}}{p_{R1}}\, dp_{R1}, \quad \text{all } r \in R.$$

The expenditure functions (4) then become, making use of equations (3) and (11),

$$(12)\qquad \begin{aligned} dm_R = &-\left(1-\frac{\partial m_R}{\partial m}\right)\left(\theta\,\frac{\partial m_R}{\partial m}-m_R\right)\frac{dP_R}{P_R} \\ &+\frac{\partial m_R}{\partial m}\sum_{K\neq R}\left(\theta\,\frac{\partial m_K}{\partial m}-m_K\right)\frac{dP_K}{P_K} \\ &+\frac{\partial m_R}{\partial m}\,dm \end{aligned}$$

where $P_R = p_{R1}$ is taken as the group price index. The corresponding quantity index is $Q_R = m_R/p_{R1}$ so that $P_RQ_R = m_R$. Using $dm_R = P_RdQ_R + Q_RdP_R$, the total differential of the demand equation for the aggregate commodity Q_R is

$$(13)\qquad \begin{aligned} dQ_R = &-\frac{\partial Q_R}{\partial m}\left[\theta\left(\frac{Q_R}{m_R}-\frac{\partial Q_R}{\partial m}\right)+Q_R\right]dP_R \\ &+\frac{\partial Q_R}{\partial m}\sum_{K\neq R}\left(\theta\,\frac{\partial Q_K}{\partial m}-Q_K\right)dP_K \\ &+\frac{\partial Q_R}{\partial m}\,dm. \end{aligned}$$

It yields the commonly used price elasticities for a pointwise separable partition,[6]

$$(14)\quad E_{RR} = -\frac{\theta}{m}\eta_R(1 - w_R\eta_R) - w_R\eta_R$$

$$(15)\quad E_{RK} = -\eta_R w_K\left(1 - \frac{\theta}{m}\eta_K\right), \qquad R \neq K.$$

If the separable subfunctions in the utility function are homogeneous of degree one, all the second-stage group expenditure elasticities, $\eta_{r/R}$, are equal to one. In this case the expenditure functions (4) become, making use of equation (3),

[5] In the money flexibility schedules (equations 9 and 10), assumption is made that all the other variables that may affect $\check{\omega}$ (habits, culture, etc.) are collinear with real income per capita. While this may be acceptable for the present purpose, especially since the forecasts of $\check{\omega}$ for Argentina in 1960–1963 are highly consistent with the point estimate for 1959 in de Janvry [15], further empirical analysis of the flexibility of money schedule and of its shifters is warranted.

[6] Where now $\eta_R = (\partial m_R/\partial m)(m/m_R) = (\partial Q_R/\partial m)(m/Q_R)$.

$$dm_R = -\left(1-\frac{\partial m_R}{\partial m}\right)\left(\theta\frac{\partial m_R}{\partial m}-m_R\right)\frac{\sum_r q_r dp_r}{m_R}$$

$$(16)\quad +\frac{\partial m_R}{\partial m}\sum_{K\neq R}\left(\theta\frac{\partial m_K}{\partial m}-m_K\right)\frac{\sum_k q_k dp_k}{m_K}$$

$$+\frac{\partial m_R}{\partial m}dm$$

which reduces to equation (12) by defining $dP_R = \sum_r q_r dp_r/\lambda_R m_R$ which integrates into the linear homogeneous price index $P_R = 1/\lambda_R$ where λ_R is the marginal utility of expenditure on group R. The corresponding quantity index is, hence, $Q_R = f_R(q_r,\ \text{all}\ r\epsilon R) = \lambda_R m_R$ where $f_R(\cdot)$ is the group subfunction in the separable utility function. The total differential of the demand equation for the aggregate commodity Q_R is again equation (13), and the price elasticities are equations (14) and (15). Both equations (12) and (16) can be integrated into equation (1) and, therefore, permit one to obtain non-local forecasts of group expenditure levels.

Direct observations of price variations show that Hicks' theorem on composite goods does not seem to hold in practice. Available estimates of the elasticities of quantities demanded of individual items in a same group—food, for example—with respect to group expenditure are generally not all equal to one, contradicting the hypothesis of homogeneous subfunctions in utility.

If, then, group quantity indexes do not exist, it is necessary to shift the emphasis from *quantities* demanded of major categories of items to group *expenditure* levels and to look for a way of determining the changes in group expenditure levels resulting from changes in the prices of specific items and in income. The first-stage expenditure functions (4) and the price indexes (3) enable prediction of these changes.

Instead of using the expenditure functions as in equation (4), one can rewrite them by analogy to equations (12) and (16) as

$$dm_R = -\left(1-\frac{\partial m_R}{\partial m}\right)\left(\theta\frac{\partial m_R}{\partial m}-m_R\right)dP_R$$

$$(17)\quad +\frac{\partial m_R}{\partial m}\sum_{K\neq R}\left(\theta\frac{\partial m_R}{\partial m}-m_K\right)dP_K$$

$$+\frac{\partial m_R}{\partial m}dm$$

by defining the group price indexes as

$$(18)\qquad dP_R = \sum_r a_r^* \frac{dp_r}{p_r}$$

where

$$a_r^* = \frac{\theta p_r \dfrac{\partial q_r}{\partial m} - p_r q_r}{\theta \dfrac{\partial m_R}{\partial m} - m_R}.$$

The advantage of rewriting equation (4) as equation (17) is that now there is a single set of slopes for the expenditure functions for whichever one of the three models holds: strong separability (equation 17), strong separability with Hicks' theorem within each separable group (equation 12), or strong separability with homogeneous subfunctions (equation 16). The difference between models is confined to the definition of the group price indexes.

The price slopes of the group expenditure functions are, with block-additivity,

$$(19)\qquad \frac{\partial m_R}{\partial P_R} = m_R(1 - w_R\eta_R)\left(1 + \frac{1}{\breve{\omega}}\eta_R\right)\cdot$$

and

$$(20)\qquad \frac{\partial m_R}{\partial P_K} = -w_R\eta_R m_K\left(1+\frac{1}{\breve{\omega}}\eta_K\right),\quad K\neq R$$

where $w_R = m_R/m$ is the budget share of group R. Except for $\breve{\omega}$, all the elements that enter into these slopes are observed or estimable from cross-section data. This is also true for the a_r^*'s which can be rewritten as

$$(21)\qquad a_r^* = \frac{w_r(\eta_r + \breve{\omega})}{w_R(\eta_R + \breve{\omega})},\quad r \epsilon R.$$

Using the 1963 budget survey [13], Table 1 gives the income elasticity η_r of each food item estimated from constant elasticity Engel functions relating expenditure on individual commodities to total food expenditure. Table 1 also gives the budget shares w_r and w_R. The expenditure elasticities, η_R, of the 14 budget categories are calculated from $\sum_{r\epsilon R} w_r\eta_r/w_R$.[7] From these

[7] For simplicity, the elasticities of individual items in the nonfood groups are not reported. The usual caveat applies; that is, the elasticities of Table 1 are, in fact, expenditure elasticities that differ from the income elasticities by the "quality" elasticities $(\partial p/\partial m)\ (m/p)$.

Table 1. Weights of group price indexes

	η_R, η_r[a]	w_R, w_r	a_r^*
Food	0.494	0.403	
Meat and fish	0.504	0.108	0.2667
Potatoes	0.337	0.022	0.0587
Fruits and vegetables	0.560	0.068	0.1633
Bread and starches	0.304	0.034	0.0921
Milk and cream	0.577	0.026	0.0699
Sugar	0.318	0.015	0.0404
Oil	0.321	0.014	0.0376
Cheese	0.679	0.012	0.0271
Non-alcoholic drinks	0.618	0.020	0.0467
Beer	1.766	0.002	0.0019
Wine	0.380	0.020	0.0524
Other alcoholic drinks	1.407	0.002	0.0028
Other foods	0.505	0.060	0.1481
Cleaning	0.475	0.024	
Health services	0.584	0.049	
Housing services	0.696	0.088	
Clothing	0.956	0.102	
Recreation	1.149	0.067	
Personal services	1.160	0.043	
Education	1.651	0.016	
Durables	1.791	0.048	
Vacation	1.987	0.022	
Servants	2.261	0.017	
Automotive expenditure	3.265	0.063	
Real property	3.344	0.016	
Other expenditures	0.694	0.036	

[a] All the estimated elasticities are significant at the 95 percent confidence level.

are obtained the weights a_r^* of the local group price indexes (equation 18). The observed yearly expenditure levels per household, m_R, on budget categories are given in the last column of Table 2. From these and the information of Table 1, the slopes—$\partial m_R/\partial P_R$ and $\partial m_R/\partial P_K$—of the group expenditure functions (12, 16, and 17) are calculated and reported in the body of Table 2.

The slopes in Table 2 give (see equation (12)) the magnitude of the change in group expenditure resulting from a rate of change of one in *all* the prices of a same group since, in this case, Hicks' theorem is satisfied. For example, if *all* food prices increase by 10 percent, the expenditure level on food increases by 1,358 pesos (1963), the automotive expenditure with a very high-income elasticity decreases by 72 pesos, etc. To trace the impact on group expenditure levels of a rate of change dp_r/p_r in the price of *one* particular item, $\partial m_R/\partial P_R$ and $\partial m_K/\partial P_R$ must be multiplied by a_r^*. For example, with a_r^* equal to .2667 for meats, a 10 percent increase in the price of meats results in a change in the price index of food of .0267. Since $\partial m_R/\partial P_R$ for food is equal to 13,579 pesos, this change induces an increase in food expenditure of 362 pesos, representing an increase of 1.7 percent above the observed level.

Estimation of Two-Stage Price and Income Elasticities

Having obtained estimates of $\check{\omega}$ and of the income elasticities η_R, η_K, and η_k from cross-section data, all that is needed to measure the price and income elasticities (equations 5, 6, and 7) for individual commodities such as food products is to estimate the second-stage parameters $(E_{rr'})_{m_R}$ and $\eta_{r/R}$ using equations (2). For this purpose, time-series data are needed on the quantities demanded of the food items of interest, on the prices of all commodities in the separable food group, and on total food expenditures.

The functional form specified for the second-stage demand equations should not imply any

Table 2. First-stage price slopes ($\partial m_R/\partial P_K$)

	Food	Cleaning	Health	Housing	Clothing	Recreation	Personal services	Education	Durables	Vacation	Servants	Automotive expenditure	Real property	Other expenditures	m_R[a]
	1963 pesos[b]														
Food	13,579	-203	-393	-665	-664	-383	-244	-59	-150	-51	-21	180	51	-272	21,011
Cleaning	-193	1,088	-22	-38	-38	-22	-14	-3	-9	-3	-1	10	3	-16	1,251
Health	-485	-29	1,916	-96	-95	-55	-35	-8	-22	-7	-3	26	7	-39	2,555
Housing	-1,038	-62	-121	3,136	-204	-118	-75	-18	-46	-16	-6	55	16	-84	4,588
Clothing	-1,653	-99	-192	-326	3,007	-188	-120	-29	-73	-25	-10	88	25	-133	5,318
Recreation	-1,306	-78	-152	-257	-257	1,777	-94	-23	-58	-20	-8	70	20	-105	3,493
Personal services	-848	-51	-99	-167	-167	-96	1,165	-15	-38	-13	-5	45	13	-68	2,242
Education	-448	-27	-52	-88	-88	-51	-32	288	-20	-7	-3	24	7	-36	834
Durables	-1,458	-88	-170	-287	-287	-166	-.105	-25	687	-22	-9	78	22	-118	2,503
Vacation	-741	-45	-86	-146	-146	-84	-54	-13	33	246	-5	40	11	-60	1,147
Servants	-651	-39	-76	-128	-128	-74	-47	-11	-29	-10	100	35	14	-53	887
Automotive expenditure	-3,488	-210	-406	-687	-685	-396	-252	-61	-155	-53	-21	-718	53	-281	3,285
Real property	-907	-55	-106	-179	-179	-103	-66	-16	-40	-14	-6	48	-244	-73	834
Other expenditures	-424	-25	-49	-84	-84	-48	-31	-7	-19	-6	-3	23	6	1,334	1,877

[a] Per capita m_R was obtained from CONADE [13] using an average family size of 3.9 according to CELADE [10].
[b] Equal to 72 cents (U.S.) per household per year.

Table 3. Two-stage price and income elasticities

	$E_{rr'}$					$E_{r.NF}$	η_r	w_r
								percent
	Beef	Lamb	Pork	Fish				
Beef	−.408[a]	.078	.101[b]	−.082[a]		−.064	.131[b]	3.39
Lamb	.042	−.245[a]	.001	.134[a]		.009	−.019	.41
Pork	.734[a]	.396[b]	−1.809[a]	.083		−.257	.527[b]	.48
Fish	.460	−.092[a]	−.031[b]	−.390		.070	−.144[b]	.12
	Milk							
Milk	−.287[a]					−.083	.169[a]	2.34
	Wheat	Rice						
Wheat	−.029	.060				−.076	.156	1.64
Rice	−.463[a]	−.453[a]				−.262	.536[a]	.14
	Potatoes							
Potatoes	−.132[a]					−.019	.038	.92
	Garlic	Onions	Tomatoes					
Garlic	−.313[a]	−.107	.158			−.383	.784	.09
Onions	−.096[b]	−.414[a]	.090			−.214	.437[b]	.14
Tomatoes	−.113[a]	−.332[a]	−.099[b]			−.326	.668[a]	.51
	Grapes							
Grapes	−.257[a]					−.174	.356[a]	1.37
	Tangerines	Apples	Oranges	Pears	Peaches			
Tangerines	−.879[a]	.655[a]	.393[a]	−.736[a]	.190[b]	−.221	.452[b]	.11
Apples	−.116	−.434[a]	.457[a]	−.173	.118	−.148	.303[b]	.33
Oranges	.261[b]	.327[a]	−1.006[a]	−.198	.063	−.254	.520[a]	.38
Pears	.027	.373[b]	.323	−1.489[a]	.618[a]	−.424	.868[b]	.08
Peaches	−.035	.232[b]	.121	−.381[b]	−.746[a]	−.401	.824[a]	.24
	Peanuts	Sunflower	Cotton seed					
Peanuts	−1.952[b]	2.483[b]	−.646			−.090	.184	.29
Sunflower	1.178[b]	−.115	−.192			−.067	.137	.62
Cotton seed	−1.103	.590	−.703			−.173	.355	.08
	Sugar							
Sugar	.509[a]					.063	−.130	1.02
	Maté	Coffee						
Maté	−.334	.170				−.107	.219	.21
Coffee	−.068	−.238[a]				−.196	.401[a]	.21

[a] Significant at the 90 percent confidence level.
[b] Significant at the 70 percent confidence level.

kind of separability among items in a same group. Constant elasticity equations were used since they are an acceptable approximation to demand functions having its empirical merits. As the number of prices in these equations is still large, a workable procedure consists of pooling into a principal components index the prices of all items that are not closely related to the quantity demanded.[8] Only the first index was retained, as it explained in all cases more

[8] There is, of course, some arbitrariness in determining which items are most closely related to others. An extensive search was made of possible groupings within the food category through factor and cluster analyses of expenditure data. Our results have been used by George and King [20, p. 38], and the present selection of related items is the same as theirs.

than 85 per cent of the total variance of the corresponding price vector. This index, which may be different for each equation, was used as a deflator of the individual prices appearing in the equation and of food expenditure.

Because the yearly consumption data for 1938–1967 were elaborated on the basis of production statistics, prices and quantities are measured at the wholesale level in raw product units, that is, in wheat instead of bread, etc.[9] The food expenditure shares from these data are, therefore, relative to food expenditure at the wholesale level, m_F:

$$w_{r/F} = p_r q_r / m_F.$$

To transform these into budget shares, the National Accounts statistics [14] were used where an average share for 1960–1963 of raw food expenditures in total consumption, $w_F = m_F/m = .15$, is given.

To calculate the two-stage price and income elasticities, $\eta_F = (\partial m_F/\partial m)(m/m_F)$ is also needed which, from the same National Accounts data and under the permanent income hypothesis, is estimated equal to .48 with a variance equal to .04 [34, p. 20].

On the basis of these two pieces of information—the predicted $\check{\omega}$ and the estimated second-stage elasticities—the two-stage elasticities from equations (5), (6), and (7) can then be calculated. In using equation (6), all other goods (NF) were assumed to be separable from raw food products. From the Engel aggregation equation, this budget category has an income elasticity of 1.09. The results for the two-stage price and income elasticities are given in Table 3. Because the flexibility of money for low-income countries such as Argentina is low, cross-group price elasticities in equation (6) tend to be negative, indicating complementarity between budget categories at low-income levels. The measures of the own-price and income elasticities appear reasonable and are generally consistent with the few estimates previously available. The cross-price elasticities generally do not satisfy the symmetry condition of the Slutsky substitution terms and are of more dubious validity.

The significance levels indicated in Table 3 pertain to the calculated two-stage parameters. Because the corrective terms relating second-stage to two-stage price elasticities are quite small, the significance levels of the first parameters are taken as approximation to the significance levels of the second. Under the assumption that the random terms in the expenditure and demand equations represent errors in the maximization process of the utility function, the residuals will not be correlated when they belong to equations corresponding to different decisions. For this reason, there is no correlation between the residuals in the first-stage expenditure functions and the residuals in the second-stage demand equations. Neither are the residuals in the second-stage equations correlated with each other when they pertain to different budgeting categories. Hence,

$$\mathrm{Cov}\,(\eta_F, \eta_{r/F}) = \mathrm{Cov}\,(\eta_{r/F}, \eta_{k/K}) = 0.$$

Significance levels of the second-stage income elasticities are calculated from the student t distribution of the product of estimators in equation (7) using for the variance the approximation,

$$\mathrm{Var}\,(\eta_r) = \eta_F{}^2\,\mathrm{Var}\,(\eta_{r/F}) + \eta_{r/F}{}^2\,\mathrm{Var}\,(\eta_F).$$

Estimates of all cross-price elasticities between food products are not available since in each second-stage demand equation fitted a number of prices were collapsed into a principal components index to save on degrees of freedom and avoid multicollinearity. Further assumptions on the structure of the utility function would be necessary to derive them from available parameters. If one accepts making the restrictive assumptions that subgroups within food items are block-additively separable as, for example, in George and King [20, p. 38], all cross-price elasticities could then be recuperated from equation (6).

[9] Because of this, the budget share and income elasticity of food in Table 1, which are measured at the retail level cannot be used.

References

[1] AMUNDSEN, A., "Private Consumption in Norway," in *Europe's Future Consumption*, ed., Jan Sandee, Amsterdam, North-Holland Publishing Co., 1964.

[2] BARREIROS, I., A. FUCARACCIO, AND F. HERSCHEL, "Funciones de Consumo en la Argentina," Paper delivered to the 2nd Meeting of the Argentine Economic Association, Dec. 1965.

[3] BARTEN, A. P., "Consumer Demand Functions Under Conditions of Almost Additive Preferences," *Econometrica* 32:1–38, Jan.–April 1964.

[4] ———, "Estimating Demand Equations," *Econometrica* 36:213–251, April 1968.

[5] BOOTH, E. J. R., AND G. G. JUDGE, "The Impact of the Choice of Model on Measurements of Economic Behavior Relationships," *J. Farm Econ.* 38:570–583, May 1956.

[6] BOUTWELL, WALLACE K., JR., AND RICHARD L. SIMMONS, "Estimation of Demand for Food and Other Products Assuming Ordinally Separable Utility," *Am. J. Agr. Econ.* 50:366–378, May 1968.

[7] BRANDOW, G. E., *Interrelations among Demands for Farm Products and Implications for Control of Market Supply*, Pennsylvania Agr. Exp. Sta. Bull. 680, Aug. 1961.

[8] BURK, MARGUERITE C., "Changes in the Demand for Food from 1941 to 1950," *J. Farm Econ.* 33:281–298, Aug. 1951.

[9] ———, *Trends and Patterns in U. S. Food Consumption*, USDA, ERS Agr. Handbook 214, 1961.

[10] CELADE, "Estimación del Número de Hogares Familiares según Sexo-Edad del Jefe, 1960–1980, Argentina," Series C, No. 83, Santiago de Chile, 1968.

[11] CHETTY, V. K., "Pooling of Time Series and Cross Section Data," *Econometrica* 36:279–290, April 1968.

[12] COCHRANE, W., AND H. LAMPE, "The Nature of the Race Between Food Supplies and Demand in the United States," *J. Farm Econ.* 35:203–222, May 1953.

[13] CONADE, "Estudios de Politica Fiscal en la Argentina," Bull. 65, Vol. VI, Buenos Aires, 1967.

[14] CONADE-CEPAL, "Distribution del Ingreso y Cuentas Nacionales en Argentina," Buenos Aires, 1965.

[15] DE JANVRY, A., "Estimacion de Sistemas de Ecuaciones de Gastos y Demanda," *Economica* 16:31–59, La Plata, Jan. 1970.

[16] ———, AND JURG BIERI, "On the Problem of Degrees of Freedom in the Analysis of Consumer Behavior," *Am. J. Agr. Econ.* 50:1720–1736, Dec. 1968.

[17] DILLON, J., AND A. POWELL, "Un Modelo Econométrico de la Demanda al Detalle en Santiago de Chile," *Cuadernos de Economia* 2:31–38, Sept.–Dec. 1965.

[18] FOX, KARL A., "Structural Analysis and the Measurement of Demand for Farm Products," *Rev. Econ. & Stat.* 36:57–66, Feb. 1954.

[19] FRISCH, RAGNAR, "A Complete Scheme for Computing All Direct and Cross Demand Elasticities in a Model with Many Sectors," *Econometrica* 27: 177–196, April 1959.

[20] GEORGE, P. S., AND G. A. KING, *Consumer Demand for Food Commodities in the United States with Projections for 1980*, Giannini Foundation Monograph 26, University of California, Davis, 1971.

[21] GIRSHICK, M. A., AND TRYVE HAAVELMO, "Statistical Analysis of the Demand for Food: Examples of Simultaneous Estimations of Structural Equations," *Econometrica* 15:79–110, April 1947.

[22] GOLDBERGER, ARTHUR S., AND THEODORE GAMALETSOS, "A Cross-Country Comparison of Consumer Expenditure Patterns," *European Econ. Rev.* 1:357–400, Spring 1970.

[23] GOLDMAN, S. M., AND H. UZAWA, "A Note on Separability in Demand Analysis," *Econometrica* 32:387–398, July 1964.

[24] GORMAN, W. M., "Separable Utility and Aggregation," *Econometrica* 27:469–481, July 1959.

[25] GRUEN, F. H., *et al.*, *Long Term Projections of Agricultural Supply and Demand, Australia, 1965–1980*, Clayton, Victoria, Australia, Department of Economics, Monash University, 1968.

[26] HOUTHAKKER, H. S., AND LESTER D. TAYLOR, *Consumer Demand in the United States: Analyses and Projections*, 2nd ed., Cambridge, Harvard University Press, 1970.

[27] JOHANSEN, LEIF, *A Multi-Sectoral Study of Economic Growth*, Amsterdam, North-Holland Publishing Co., 1960.

[28] La Molina Universidad Agraria, Programma de Investigaciones para el Desarrollo, *Peru: Long Term Projections of Demand for and Supply of Selected Agricultural Commodities Through 1980*, prepared for USDA, ERS, Jerusalem, Israel, Program for Scientific Translations, 1969.

[29] MUNDLAK, YAIR, *Long-Term Projections of Supply and Demand for Agricultural Products in Israel. I. General View and Summary*, Falk Project for Economic Research in Israel, The Hebrew University, Jerusalem, 1964.

[30] NUÑEZ, A., "A Quantitative Macroeconomic Study of Argentinian Agriculture," unpublished Ph.D. thesis, University of California, Berkeley, in preparation.

[31] PEARCE, I. F., "An Exact Method of Consumer Demand Analysis," *Econometrica* 29:499–516, Oct. 1961.

[32] POWELL, ALAN, "Post-War Consumption in Canada: A First Look at the Aggregates," *Canadian J. Econ. & Polit. Sci.* 31:559–565, Nov. 1965.

[33] ———, "A Complete System of Consumer Demand Equations for the Australian Economy Fitted by a Model of Additive Preferences," *Econometrica* 34:661–675, July 1966.

[34] SJAASTAD, L., "Comsumption Patterns in Argentina," Department of Economics, University of Chicago, 1966, mimeo.

[35] STONE, J. R. N., "Linear Expenditure Systems and Demand Analysis: An Application to the Pattern of British Demand," *Econ. J.* 64:511–527, Sept. 1954.

[36] STROTZ, ROBERT H., "The Utility Tree—A Correction and Further Appraisal," *Econometrica* 27:482–488, July 1959.

[37] SUITS, D., AND G. SPARKS, "Consumption Regressions with Quarterly Data," in *The Brookings Quarterly Econometric Model of the United States*, eds., James S. Dusenberry *et al.*, Chicago, Rand McNally and Co., 1965, Chap. 7.

[38] THEIL, HENRI, *Economics and Information Theory*, Amsterdam, North-Holland Publishing Co., 1967.

[39] TOBIN, JAMES, "A Statistical Demand Function for Food in the USA," *J. Royal Stat. Soc.* 113 (Series A, Part II):113–141, 1950.

[40] TOLLEY, G. S., Y. WANG, AND R. G. FLETCHER, "Reexamination of the Time Series Evidence on Food Demand," *Econometrica* 37:695–705, Oct. 1969.

[41] TWEETEN, LUTHER G., "The Demand for United States Farm Output," *Food Res. Inst. Stud.* 7:343–369, 1967.

[42] U. S. Department of Agriculture, *Agricultural Statistics, 1967*, 1968.

[43] WAUGH, FREDERICK V., *Demand and Price Analysis. Some Examples from Agriculture*, USDA Tech. Bull. 1316, Nov. 1964.

[44] ZELLNER, ARNOLD, "An Efficient Method of Estimating Seemingly Unrelated Regressions and Tests for Aggregation Bias," *J. Am. Stat. Assn.* 57:348–368, June 1962.

An Econometric Analysis of Shrimp Ex-Vessel Prices, 1950-1968*

JOHN P. DOLL

A five-equation demand model of the U.S. shrimp market was estimated using annual data for the period from 1950 to 1968. Prices, consumption, and ending stocks were the jointly determined variables; predetermined variables were shrimp supplies and consumer income. Ex-vessel price variations resulted largely from variations in domestic landings. Imports reduced the general level of ex-vessel prices but did not contribute substantially to price variability except in isolated instances. Large price drop occurred during periods of recession when increases in demand were slowed and stocks began to build, while landings and imports increased substantially over the previous year.

SHRIMP CONSUMPTION in the United States has expanded steadily over the past two decades. The estimated total consumption of shrimp in 1968 was 306.6 million pounds, an increase of 259 percent since 1950.[1] While part of this expansion resulted from an increasing population, per capita consumption of shrimp doubled at a time when per capita consumption of all fish products remained virtually constant.

The increased consumption of shrimp could not occur, of course, without a similar increase in supply. The two sources of supply are landings by domestic fishermen and imports from foreign countries.

From small beginnings in the 1940's, domestic shrimping has emerged as the leading U. S. fishery, measured in value of landings. By 1968 shrimp landings were valued at about $100 million, representing approximately one-fourth of the value of all landings of major U. S. fisheries. During the last 20 years, however, the increase in the value of domestic shrimp landings has been due to increasing price levels rather than increasing production. In fact, landings since 1950 have varied greatly from year to year but have exhibited no discernible time trend. Peak landings for the period, 158.2 million pounds, occurred in 1954 and were 1.7 times the low, 91.2 million pounds, which occurred in 1961. The average of domestic landings for 1950–68 was 131.0 million pounds and the standard deviation was 16.8 million pounds, about 13 percent of the mean.

The large increase in supply since 1950 has come from the other major source of shrimp: foreign imports. Imports were about one-third the size of domestic landings in 1950 but began to increase rapidly in 1955 and have exceeded domestic landings in every year since 1961. The increase was steady; only the size varied from year-to-year. By 1968, imports totaled 201.2 million pounds (excluding transshipments that entered as imports), compared to southern landings of 142.9 million pounds.

Annual imports and domestic landings, when added to holdings in cold storage at the beginning of the year, make up total annual supply of shrimp. Although this total annual supply has been increasing since 1950, consumer demand over the period has also increased, as evidenced by the consumption figures cited previously, so that shrimp prices have moved upward (Fig. 1). Ex-vessel price increased from $0.36 in 1950 to $0.76 in 1968; wholesale price increased from $0.62 in 1950 to $1.20 in 1968; and retail price increased from $0.79 in 1950 to $1.35 in 1968. (All prices are quoted per pound.) These are increases of $0.40, $0.58, and $0.56, respectively. But within the longtime trend, shrimp prices have fluctuated considerably. Large price decreases occurred in 1954, 1959, 1963, and 1967.

The rapid expansion of the shrimp market has stimulated economists' interest in the subject. Cleary [3] estimated single equation demand functions for shrimp, while Gillespie, Hite, and Lytle [6] developed a simultaneous

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[1] All data for domestic consumption and production will be based on landings in the South Atlantic and Gulf states. Although the catch from the Alaska and Maine shrimp fisheries has increased rapidly in recent years, production from these areas was small relative to the Southern catch during the period of study. The small-sized Northern shrimp generally do not enter the same markets as Southern shrimp. Data from the New England and Pacific fisheries are therefore omitted throughout this report. All quantity data are expressed in heads-off weight.

JOHN P. DOLL *is a professor of economics at the University of Missouri.*

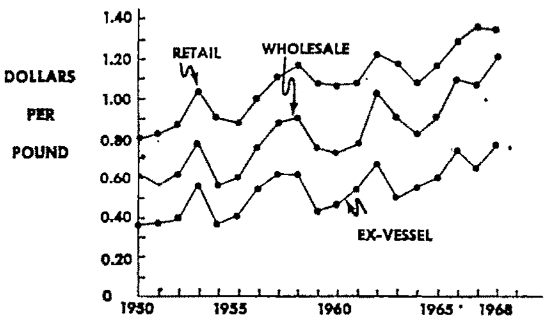

Figure 1. Retail, wholesale, and ex-vessel shrimp price, United States, 1950–1968

equation model directed toward the evaluation of import quotas. Wilson, Thompson, and Callen [12] developed optimal investment policies for individual shrimp fishermen. Accordingly, the purpose of the present study is to specify and estimate a structural model of the U. S. shrimp market with the hope of adding to the developing store of knowledge of the underlying behavioral relationships in the market. First, the model will be described and discussed. Then, although other applications are possible, its use will be illustrated by determining the effects of various exogenous variables upon ex-vessel prices.

An Annual Model

General discussion

The shrimp market is composed of three general sectors: domestic landings, wholesale (including imports), and retail. A model that is complete in the economic sense would include a supply and demand equation for each of these sectors. Further, one or more equations explaining such supply variables as vessel numbers and tonnage or number of fishermen would be useful. However, when the ideal model was confronted with the realities of available data, some compromises became necessary.

The existing data for the U. S. shrimp market consist of supplies entering the market (imports, domestic landings, and beginning cold storage holdings), the market prices (ex-vessel, wholesale, and retail), and quantities "consumed" (consumption per se and ending cold storage holdings). Data are not available to quantify what happens in between; for example, quantities moving through wholesale channels or held in storage at retail levels are not recorded.

Further, measures of the appropriate variables influencing supply were not available. Preliminary specifications suggested that domestic landings were not related to either craft numbers or the available measures of tonnage. The National Marine Fisheries Service does collect data on fishing effort, but this measure also is not related to landings. In his definitive study of the Gulf shrimp population, Berry [1, p. 17] came to the conclusion that annual fluctuations in landings reflect changes in abundance of shrimp rather than in fishing effort.

The factors that cause shrimp abundance are biological in nature and exogenous to the market place. Further, the lack of a trend in successive generations of shrimp suggests that one year's catch does not affect abundance the next year [1, p. 19]. The biological factors causing shrimp abundance are not clearly identified and cannot be forecast. Thus, domestic landings are both variable and unpredictable and are regarded as exogenous in the model.

Imports were also assumed to be exogenous in the model, although the import sector is inherently more complex than domestic production. The single largest source of imports is from countries surrounding the Gulf, and the volume of these imports is subject in part to the same variations as domestic supply. Some importers are domestic firms that maintain foreign fleets and simply import their entire catch. Some U. S. importers also buy on forward contracts. Although foreign suppliers have a choice of marketing areas, prices in the United States are favorable relative to other markets and some fisheries have apparently been developed with the lucrative U.S. market in mind. The result is that there is not just one import market but many. In the absence of a good descriptive study and data that would lead to a more sophisticated specification, imports were regarded as exogenous. Because domestic landings cannot be forecast, importers' expectations are thus assumed to respond primarily to variables such as beginning cold storage holdings and consumer income (market expansion).[2]

The resulting model is essentially a demand model. It is specified so that predetermined supplies and consumer income determine prices, which in turn determine retail consumption and ending cold storage holdings.

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[2] The simple correlation of imports with domestic landings is −0.03 and with landings lagged one year is −0.05, suggesting that importers' decisions are not greatly influenced by either of these variables.

Variables in the model

The five jointly determined (endogenous) variables included in the model are

P_r'—retail shrimp price, raw headless frozen (for 1950–1964, New York City; 1964–1968, BLS U.S. city average).
P_w'—wholesale shrimp price, 26–30 count, frozen processed, BLS Chicago.
P_e'—ex-vessel shrimp price, South Atlantic and Gulf states.
C'—total annual shrimp consumption, millions of pounds.
S'—end-of-year stocks held in cold storage, millions of pounds.

The six predetermined (exogenous and lagged endogenous) variables included in the model are

L—domestic landings, South Atlantic and Gulf states, millions of pounds.
S_{t-1}—stocks held in cold storage at the beginning of the year, millions of pounds.
Y—actual total disposable personal income in the United States, millions of dollars.
I—total imports, millions of pounds.
$P_{e_{t-1}}$—ex-vessel price lagged one year.
1—the intercept dummy variable.

All variables are measured over the calendar year, 1950–1968, inclusive. Variables without subscripts $(t-1)$ are for the current year, whereas variables with the subscript $(t-1)$ denote one-year lags. Prices are dollars per pounds. For ease of identification, primes are placed on jointly determined variables and omitted on predetermined variables.

Formulation of the model

In this section each equation in the model will be presented and discussed. Preliminary specification and estimation suggested that the equations below are a meaningful representation of the shrimp market, given the limitations of the data and the purpose for which the model is intended. There are five behavioral equations and no identities. Each equation is written in normalized form; when more than one jointly determined variable appeared in an equation, the variable to be normalized was selected to conform with conventional economic theory. The disturbance for each equation is denoted u_i where i is the equation number and the subscript t is omitted, as it is on all current variables.

Retail Demand:

$$C' = \alpha_0 + \alpha_1 P_r' + \alpha_2 Y + u_1. \tag{1}$$

Total retail consumption, C', represents an aggregate estimate of the consumption of shrimp for all uses, including fresh and frozen, breaded, and other specialty forms. Retail price appears as a proxy for the price of shrimp in all these uses. Total income, Y, used as a demand shifter, is correlated with time, as is population. While inclusion of any one of these three variables might have similar effects, income was used because it seemed reasonable to expect that shrimp should be somewhat more sensitive to income changes.

Economic theory suggests that in addition to own-price and income, the prices of all other commodities consumed should be included in the demand equation. Shrimp undoubtedly do have complementary or substitution effects with other seafoods and meats but none could be isolated in preliminary specifications. Apparently, the aggregate nature of the data masked such effects. Because the nature of retail demand is quite important to the overall functioning of structural model, the present equation, although crude by theoretical standards, was needed. Cleary [3] has discussed the demand for shrimp in further detail.

Wholesale Demand:

$$P_w' = b_0 + b_1 S_{t-1} + b_2 L + b_3 I + b_4 Y + u_2. \tag{2}$$

Wholesale shrimp price in any year is in part a function of available supplies: beginning stocks, landings, and imports. These variables were included in the wholesale price equation and can be regarded as surrogates for the nonmeasured variable "wholesale quantity." As a derived demand, the wholesale market should demonstrate an expansion over time similar to that of the retail market, and income is included to capture that effect.[3]

Ex-vessel Demand:

$$P_e' = c_0 + c_1 S_{t-1} + c_2 L + c_3 I + c_4 Y + u_3. \tag{3}$$

The strength of demand at the ex-vessel level should depend upon domestic landings, L, as well as supplies available from other sources,

[3] While a price level equation could have been used, this formulation was chosen because it relates wholesale price directly to sources of supply and income.

that is, stocks held in cold storage at the beginning of the year, S_{t-1}, and imports, I. Also, ex-vessel prices are subject to the same shifts in demand over time as are retail and wholesale demand; therefore, total income, Y, was included in this equation as a shift variable.

(4) Price Level:

$$P_r' = d_0 + d_1 P_w' + d_2 P_{e_{t-1}} + u_4.$$

As examination of Figure 1 illustrates, prices in the shrimp market tend to move together. The purpose of the price level relation is to insure that retail prices predicted by the reduced form will move with wholesale price. Predicted ex-vessel price and predicted wholesale price will move together because they are expressed as functions of the same explanatory variables. A principal component analysis of the prices suggested that wholesale price is an excellent index of retail price and that a one-year lag often exists between retail and ex-vessel price [4]. Thus, current wholesale price and ex-vessel price lagged one year were included in the relation. Although price level equations such as this one are a common device in econometric models [5, p. 8; 10, p. 471], such an equation would not be required in the present model if data were available to permit a more complete specification.

Stock Balance:

(5) $S' = e_0 + e_1 S_{t-1} + e_2 L + e_3 I + e_4 C' + u_5.$

Cold storage holdings at the end of the year, S', depend upon supplies and consumption during the year. Thus, S' and C' were specified in relation with imports, I, beginning stocks, S_{t-1}, and landings, L. When supplies are high, consumption will increase during the year but not to the extent that all additional supplies disappear. Thus, ending stocks should increase as total supply increases. Similarly, other things being equal, an increase in consumption during the year should decrease stocks.

Stocks are accumulated when shrimp landings and imports are high in the fall of the year and are used to meet demands during the early months of the year when landings are small. Furthermore, a part of the stocks are undoubtedly "pipeline" in nature, that is, being held for further processing or transporting. Frozen shrimp cannot be held long periods without deterioration and, even though domestic landings are unpredictable, speculation does not appear to be the major purpose for holdings. Stocks are small relative to annual supplies and a large portion of holdings would seem to be for supply purposes. Prices and expectational variables were therefore excluded from the relation. Because it is essentially an empirical relationship among supply and consumption variables, the stock balance relation serves in part the same role as a market clearing identity.[4]

Estimates of the annual shrimp model, 1950–1968

Statistical considerations.—All equations in the model are identified. The wholesale and ex-vessel demand equations each contain exactly one jointly determined variable and were estimated using ordinary least squares. The other three equations were estimated using three-stage least squares. A complete discussion of the statistical assumptions that must be made to enable a system of linear equations to be estimated are presented by Christ [2, pp. 350–357].

All data used were obtained directly from the Economics Research Laboratory, National Marine Fisheries Service, College Park, Maryland. All quantities and prices are based on the calendar year. Landings and consumption were derived using South Atlantic and Gulf states landings, and imports were adjusted for transshipments through this country that are listed as imports to the U.S. but are actually exports from one foreign country to another.

Estimated equations.—Estimates of the equations are contained in Table 1. Coefficients are presented to the first four digits or four decimals. The standard errors of the coefficients of each equation are placed in parentheses below the coefficients. Although conventional tests of significance are not exactly applicable to parameters obtained from most methods of estimating simultaneous equation models [2, p. 515], the standard error does provide a guide for applied work. Durbin-Watson statistics were not computed for the equations estimated using three-stage least squares because their interpretation would not be unambiguous. Estimates analogous to the R^2 of ordinary least

[4] An identity would have to include all sources of demand and would require the addition of exports and canning demand to the model. These categories are small relative to total volume of the market and an attempt to include them in the model resulted in meaningless coefficients. They apparently respond to different variables than were included in this model and were thus omitted to conserve degrees of freedom.

Table 1. Estimated structural coefficients for annual shrimp model, 1950–1968[a]

Equation	Jointly Determined Variables					Predetermined Variables						R^2	D.W.
	C'	S'	P_r'	P_w'	P_e'	1	Y	S_{t-1}	L	I	$P_{e_{t-1}}$		
Retail demand (6)	1	—	−119.3 (46.0)	—	—	104.5 (31.10)	0.6445 (0.0628)	—	—	—	—	—	—
Wholesale demand (7)	—	—	—	1	—	0.5872 (0.0403)	0.0023 (0.0005)	−0.0082 (0.0016)	−0.0022 (0.0009)	−0.0002 (0.0010)	—	0.93	1.47[b]
Ex-vessel demand (8)	—	—	—	—	1	0.4992 (0.1072)	0.0022 (0.0004)	−0.0047 (0.0013)	−0.0032 (0.0007)	−0.0016 (0.0008)	—	0.91	1.78[c]
Price level (9)	—	—	1	0.6937 (0.0682)	—	0.3354 (0.0845)	—	—	—	—	0.3423 (0.0973)	—	—
Stock balance (10)	−0.8879 (0.1256)	1	—	—	—	−3.174 (5.175)	—	0.9450 (0.1567)	0.7455 (0.0861)	0.8534 (0.0966)	—	—	—

[a] Standard errors of coefficients are placed in parentheses.
[b] Durbin-Watson statistic is inconclusive.
[c] Durbin-Watson indicates no serial correlation.

squares would have no interpretation at all for the structural equations with more than one endogenous variable and were therefore not computed [2, p. 519].

All coefficients in the model have signs consistent with prior theoretical expectations. In the interest of brevity, a detailed discussion of each equation will not be presented, but some highlights will be noted.

The price elasticity of demand at the mean of price and consumption is −0.63. The institutional demand for shrimp comprises an important part of the final market, and the cost of preparation and other services would be an important determinant of the price of the prepared food. Consumption under these conditions would not be responsive to changes in price alone. Consumption by individual consumers, which might be expected to be more responsive to retail price, could possibly be masked by the institutional demand.[5] On the other hand, shrimp may comprise such a small portion of the food budget that even individual consumers are not sensitive to price changes. At any rate, this elasticity should not be regarded as the final word.

The income elasticity is 1.12 at the means. Even when the other factors collected by the income variable are discounted, it is quite possible that the "pure" income elasticity could exceed unity and that shrimp are therefore income elastic.

The price flexibility for landings is −0.79 at the means. The inverse of the price flexibility is the lower limit of price elasticity; therefore, the ex-vessel demand function is price elastic ($\epsilon_p = -1.27$) [8]. If so, then increased landings mean a decrease in price but an increase in total revenue to fishermen. But this measure is taken at the means, with other variables held constant.[6]

A comparison of the wholesale and ex-vessel demand equations suggests that imports have a larger direct impact on ex-vessel price than on wholesale price. This is something of a surprise. Also, beginning stocks affect both wholesale and ex-vessel prices but have a larger direct effect upon wholesale price. Imports enter throughout the year but are largest in the fourth quarter. Thus, a possible explanation is that imports are placed in storage and sold during the first and second quarters when domestic landings are seasonally low. The effect of imports on wholesale price is thereby reflected through beginning stocks for the next year. Beginning stocks also have an important effect on ex-vessel price. Thus, over time, imports will have a lag effect on both prices.

The reduced form.—The restricted reduced form for the annual shrimp model is presented

[5] Unfortunately, data are not available to permit estimation of separate demand functions for each of the sectors.

[6] A deflated model was also estimated and is available from the author. Because deflating would appear to reduce price and income variations while leaving quantity variations unchanged, deflating would generally be expected to increase elasticities. After deflating, the elasticities (at the mean) were −1.15 for retail price and 1.52 for income and the ex-vessel price flexibility for landings was −0.77. Thus, retail price and income elasticities increased while ex-vessel price elasticity was virtually unchanged by deflating. Elasticities are measures traditionally used in single equation analyses; it is of interest to compare them to an alternative estimate using the structural model. Using reduced form equations (12) and (15), the effects of increased landings over the entire study period were simulated. When landings were arbitrarily increased 5 and 10 percent, the estimated ex-vessel price elasticity for the total period was −0.63. Other exogenous variables were assumed to take their actual values. This method traces the effect of increased landings through the entire market.

Table 2. Reduced form coefficients for annual shrimp model, 1950–1968

Equation Number	Jointly Determined Variables		Predetermined Variables					
			Intercept value 1	Total income[a] Y	Beginning stocks[b] S_{t-1}	Landings[b] L	Imports[b] I	Lagged ex-vessel price $P_{e_{t-1}}$
11	Consumption	C'	15.8911 (15.3551)	0.4542 (0.0596)	0.6786 (0.3011)	0.1821 (0.1032)	0.0166 (0.0846)	−40.8364 (22.1443)
12	Ending stocks	S'	−17.2837 (13.8266)	−0.4032 (0.0760)	0.3425 (0.1929)	0.5838 (0.1145)	0.8387 (0.1207)	36.2586 (16.2937)
13	Retail price	P_r	0.7427 (0.0842)	0.0016 (0.0004)	−0.0057 (0.0013)	−0.0015 (0.0006)	−0.0001 (0.0007)	0.3422 (0.0973)
14	Wholesale price	P_w	0.5872 (0.1072)	0.0023 (0.0005)	−0.0082 (0.0016)	−0.0022 (0.0009)	−0.0002 (0.0010)	—
15	Ex-vessel price	P_e'	0.4992 (0.0845)	0.0022 (0.0004)	−0.0047 (0.0013)	−0.0032 (0.0007)	−0.0016 (0.0008)	—

[a] Millions of dollars.
[b] Millions of pounds, heads-off weight.

in Table 2. Again, the coefficients have the signs that would be expected *a priori*. The reduced form equations for wholesale and ex-vessel price are the same as the structural equations.

The reduced form equations can be used to predict values of the jointly determined variables. For each jointly determined variable, the percentage of the total sums of squares about the mean "explained" by its reduced form equation is as follows: consumption, 97 percent; ending stocks, 48 percent; retail price, 91 percent; wholesale price, 93 percent; and ex-vessel price, 91 percent. Although the fits provided by the reduced form are good, a graphic analysis (not presented) suggested that they predict values near the average quite well, but sometimes fail to predict extreme values.

Analysis of Supply and Demand Variations Upon Ex-vessel Prices

The problem

The model presented could have a variety of uses. However, it will be used here to analyze a problem that has been of concern to the shrimp industry in recent years, namely, the impact of imports upon domestic ex-vessel prices. All is not well for domestic shrimp fishermen. Although no trend is evident in domestic landings, the number of craft used for shrimping increased from 6,730 in 1950 to 9,501 in 1968 and the number of fishermen increased from 14,400 in 1950 to 16,800 in 1966. As a result, landings per fisherman and landings per craft have fallen consistently since 1953. But due to increasing price levels, the value of output per fisherman has increased over the period while the value of output per craft has remained relatively constant.[7] Costs of course have increased over the last 20 years and, faced with a cost-price squeeze in addition to the inherent variability of domestic ex-vessel prices, domestic producers have debated the effects of imports upon price levels and variability [11, pp. 8–9].

For the period studied, shrimp imports were not subject to either quotas or duties. In view of their magnitude, it seems reasonable to infer that domestic prices are lower than they would be in the absence of imports. The question is: How much lower? But is it also true that problems of price variability can be attributed in total to imports? Answers to these questions will now be attempted.

Short- and long-run multipliers

Impact, cumulative, and equilibrium multipliers can be used to measure the relative effects of exogenous variables. Impact multipliers are the reduced form coefficients of the exogenous

[7] These figures are average and in a competitive industry the earnings are not evenly distributed among firms. The increase in craft numbers over the period is due largely to an increase in boats. Vessel numbers (craft of five net tons or over) reached a peak of 4,227 in 1959 and in recent years has stabilized at about 3,800. Vessel tonnage did increase somewhat over this period, indicating that larger vessels are being built. These larger vessels can range further from port and may have profit advantage over other vessels. More background is given by Gillespie, Hite, and Lytle [6] and Osterbind and Pantier [9].

variables and measure the effect of a one-unit change in an exogenous variable upon the value of the endogenous variable in the same time period. Thus, the effects of a one-unit change in landings or imports can be compared by comparing their impact multipliers in Table 2. Landings have a far greater impact on prices and consumption in the current year. For ex-vessel price, the landings coefficient is −0.0032 and the import coefficient is −0.0016, exactly half the size of the landings coefficient. However, imports have a greater effect on ending stocks. As mentioned, a significant portion of imports apparently flow directly to storage and therefore have a smaller direct effect on prices and consumption than landings, which must move directly through markets in domestic ports. Beginning stocks do have a significant impact on prices and consumption and the effect of imports are thus reflected indirectly.

A measure of the actual impact the two have should also consider the rate of flow of each variable. Domestic landings have not trended upward since 1950 but have had a mean of 131.0 million pounds with a standard deviation of 16.8 million pounds. In six of the 19 years, domestic landings fell outside the limits 131.0 ±16.8. Imports, on the other hand, simply increased over the period from 40.1 million pounds in 1950 to 201.2 million pounds in 1968. The average *rate of increase* for imports was 8.9 million pounds per year. When the impact multipliers for landings and imports are multiplied by 16.8 and 8.9, respectively, the resulting effect on ex-vessel price is −0.0538 dollars per pound (landings) and −0.0143 dollars per pound (imports).

This comparison of the direct effects of landings and imports within the year of change suggests that landings have both a larger unit effect and a larger total effect on ex-vessel prices, given the assumed changes in each variable. But in any given year, the actual effects would depend on the actual values that occurred. A comparison of the effects of actual year-to-year changes in ex-vessel prices was determined by a simple marginal analysis. To do so, the change in each variable between years in the sample period was multiplied by that variable's coefficient in equation (15), the ex-vessel demand equation, to find the resulting predicted change in ex-vessel price. The results are shown for the 1950–1968 period in Figure 2. (Income is included; its effect will be discussed in more detail in the next section.) Visual inspection of the graph verifies the nature of the impact of each variable.

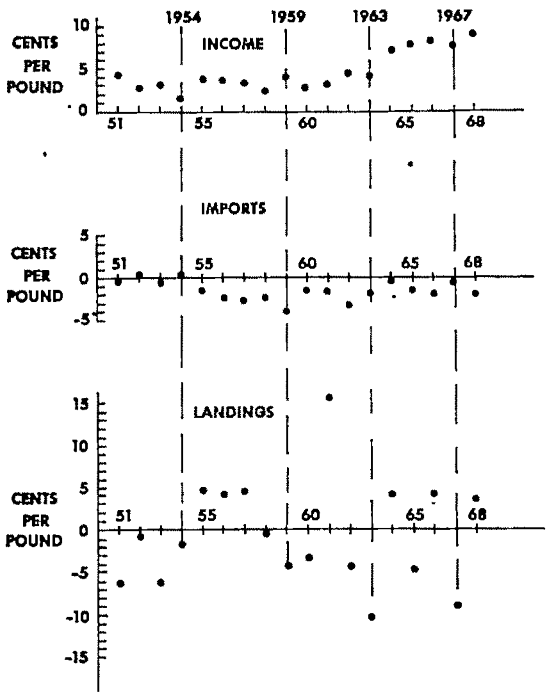

Figure 2. Predicted marginal changes in ex-vessel price resulting from changes in exogenous variables

Of the three exogenous variables, domestic landings had both the largest and most variable effect on prices. In 18 years, the marginal impact of landings changed signs (direction) nine times. The largest positive increase in price, 16 cents, occurred between 1960 and 1961 when domestic landings fell 50 million pounds; the largest decrease, 10 cents, occurred between 1962 and 1963 when landings increased 33 million pounds. After 1954, import increases tended to reduce price, but the effects have been moderate since 1963. The range of the marginal import effects have been from plus one-half a cent in 1952 to minus four cents in 1959. Income has always increased and therefore has always had a positive effect on prices. Its smallest increase, one cent, occurred in 1954 and the highest, nine cents, in 1968.

Cumulative multipliers for periods up to four years and equilibrium multipliers for ending stocks and ex-vessel price are presented in Table 3. For completeness, impact multipliers are also included. The cumulative and equilibrium multipliers were derived using the reduced form equations for ending stocks (12) and ex-vessel

Table 3. Impact, cumulative, and equilibrium multipliers for annual shrimp model, 1950–1968

Type of Multiplier	Joint Variable	Exogenous Variable Y	L	I
Impact (no lag)	S'	−0.4032[a]	0.5838	0.8387
	P_e'	0.0022[b]	−0.0032	−0.0016
Cumulative (one-year lag)	S'	−0.4616	0.6678	1.0679
	P_e'	0.0041	−0.0059	−0.0055
Cumulative (two-year lag)	S'	−0.4128	0.5970	1.0035
	P_e'	0.0044	−0.0063	−0.0066
Cumulative (three-year lag)	S'	−0.3862	0.5573	0.9324
	P_e'	0.0041	−0.0060	−0.0068
Cumulative (four-year lag)	S'	−0.3854	0.5573	0.9324
	P_e'	0.0040	−0.0058	−0.0060
Equilibrium multiplier	S'	−0.3907	0.5650	0.9429
	P_e'	0.0040	−0.0059	−0.0060

[a] Stocks are measured in millions of pounds.
[b] Prices are measured in dollars per pound.

price (15), as described in Goldberger [7, pp. 373–378] and Theil [10, pp. 463–468].

Cumulative multipliers measure the effect of a one-unit increase (decrease) in an exogenous variable in a previous year upon the endogenous variable in the current period, given that the increase is maintained in all intervening periods. The lag effect of imports shows up in the cumulative multipliers. After one year's lag, the effect of a sustained one-unit increase in imports is only slightly smaller than landings and after two years, the import effect slightly exceeds that of landings. After four years, the cumulative multipliers have stabilized and differ only slightly from the equilibrium multipliers.

Equilibrium multipliers measure the long-run effect of a permanent change in an exogenous variable. The equilibrium multipliers for ex-vessel price show that the long-run effects of landings and imports are the same. This is a reasonable result because shrimp from either source are equally acceptable to the consumer. Thus, a one million pound increase in either imports or landings will reduce ex-vessel price by 0.6 cents per pound in the long run.

Multiplying the average change in income ($21.2 million per year) by its equilibrium multiplier, the average per-year equilibrium increase in ex-vessel price attributable to income increases (or, more accurately, all the market expansion variable for which income is a surrogate) would be 0.08 cents per pound. The average per-year equilibrium decrease caused by imports would be 0.05 cents per pound, leaving a net increase of 0.03 cents per pound. Thus, as a very rough estimate, imports have probably reduced ex-vessel price *increases* by 60 percent in the long run.[8]

Shrimp landings and the business cycle

Four severe price drops have occurred in ex-vessel prices since 1950: 1954, 1959, 1963, and 1967 (Fig. 1). Landings were high in three of these years; 1954, 1963, and 1967 were years of peak landings while landings in 1959 increased over the previous year. While high landings undoubtedly had a substantial direct effect upon ex-vessel prices in these years, it is also true these years were periods of slow economic growth in the United States. National income increased throughout the period, but substantial slow-downs (recessions) occurred in 1954, 1958–1960, 1963, and 1967.

Changes in income, landings, and imports over the 1950–1968 period are listed in Table 4. Examination of the table bears out the conclusion that a large increase in landings occurred at times when the economy was slowing down. The demand function for shrimp demonstrated that the income effect is important in the shrimp market—prices have increased in the face of increasing imports because the market has been expanding. Thus, for the price drops in the period studied, the decrease in price caused by increased landings was accentuated by the fact that the rate of market expansion was slowed by business recessions. (This can also be verified by a study of Figure 2; vertical dashed lines are drawn for the years when ex-vessel price dropped.)

The supply situation was somewhat different during each of the four price drops. In 1954 imports were not an important factor. Landings were high in 1953; imports increased slightly but total consumption dropped from the new peak set in 1952. As a result, stocks were high at the beginning of 1954. Landings again increased in 1954 (imports dropped slightly), and this increase, coupled with high beginning stocks and a small increase in national income, apparently caused the price break. Decreasing prices did increase total consumption, but not

[8] For the deflated model, this estimate is 66 percent. The equilibrium multipliers could be used to compute a "long-run" elasticity. For the undeflated model, the "long-run" ex-vessel price elasticity is −0.69; compare to footnote 6.

Table 4. Shrimp supplies and income changes

Year[a]	ΔLandings	ΔImports	Ending Stocks	ΔIncome
1950			25.7	
1951	19.7	1.5	27.6	19.7
1952	1.5	−3.2	15.4	11.7[c]
1953	20.0	4.5	26.4	14.3
1954	5.0[b]	−1.5	31.2	4.8[c]
1955	−14.8	12.3	21.2	17.9
1956	−13.0	14.7	21.7	17.9
1957	−14.2	1.1	28.7	15.0[c]
1958	0.4	15.4	39.2	10.3[c]
1959	14.1	25.9	46.0	19.0
1960	10.3[b]	7.5	51.0	12.7[c]
1961	−49.6	10.0	26.2	14.4
1962	14.4	21.0	37.9	20.9
1963	32.5[b]	11.6	55.8	19.3[c]
1964	−14.0	0.6	45.5	33.5
1965	15.3[b]	8.7	38.2	35.1
1966	−13.3	12.7	42.5	38.4
1967	28.2[b]	2.5	57.6	34.7[c]
1968	−11.6	15.1	55.5	42.7

[a] Years in boxes represent ex-vessel price breaks.
[b] Years in which landings exceeded those of prior or succeeding years.
[c] Years of slow-down in rate of income growth; the increase in income is smaller than the increase in the previous year.

enough to absorb the increase in supplies, and stocks ending in 1954 were the highest on record up to that time.

In 1959 the increase in income was larger than in the preceding two years. The slowdown in income had started in 1957, but its impact probably was not evident in the shrimp market because landings were below average and the increase in imports was very small. Imports increased in 1958 while landings remained low. Stocks began to increase in 1957 as a result of increasing imports and the slowdown in the economy, eventually attaining a new high at the end of 1958. Imports rose markedly in 1959 and, when landings also increased, the result was an excessive supply. Prices dropped substantially in 1959 and would have dropped more had the rate of increase in income not recovered somewhat. In 1960, landings increased to an even higher peak, but the rate of *increase* of imports dropped by 18 million pounds (the largest such decrease in the study period) and further reductions in retail and wholesale prices continued to clear the market, setting a new high in total consumption. Ex-vessel prices that year began to recover, one of the few times that ex-vessel price moved against wholesale and retail price.

The 1959 price break was unique in the study period because substantial increases in both domestic landings and imports occurred during a period of recession when stocks were building because of a slow-down in demand. In 1963, beginning stocks were again high due to a large increase in landings and imports in 1962. But in 1963, the rate of increase in imports slowed over that of 1962 and stocks were allowed to build. The "slowdown" in imports along with a substantial increase in total consumption, due in part to price declines, moderated the impact of the increase in 1963 landings. The 1963 recession was mild; based on income increases, the market expansion rate in 1963 would have exceeded that of any previous year except 1962 and 1951. The 1967 price break was accompanied by factors quite similar to the 1963 drop.

The interesting questions here are: Why did domestic landings increase during the four recessions? Are landings truly random and determined only by biological phenomena? If so, the domestic shrimp industry would appear to be simply unlucky. Or, do shrimp fishermen increase fishing effort and land additional shrimp when price is low? The lack of a well-defined domestic supply function for shrimping prevents a complete answer to this question at this time. However, if landings can be assumed to be random, a partial answer can be given.

The reduced form equation for ex-vessel price gives the expectation of the random variable ex-vessel price conditioned on values of the predetermined variables. Assume for the following analysis only that domestic landings are normally distributed with a mean of 131.0 million pounds and a standard deviation of 16.8 million pounds and that the error about the regression equation is also normal with a mean of zero and a standard deviation equal to the standard error of estimate. From these assumptions it follows that ex-vessel price in any year is a normally distributed random variable with a known variance and a mean that can be computed from equation (15) using the actual values of beginning stocks, imports, income, and the expected value of landings.[9] By using these assumptions and by allowing imports to enter at

[9] Landings as a random variable are assumed to be independent of the error term, an assumption that would be necessary for estimation in any case.

the actual rate, the probability of a price break can be computed.

Using this analysis, the probabilities that the ex-vessel prices in 1954, 1959, 1963, and 1967 would each be less than the prices of the previous year are 0.58, 0.99, 0.98, and 0.26. Thus, in 1959 and 1963, the supply and demand situation made a price drop a virtual certainty. Landings those years were not unusually high; in 1959 they were 130.7 million pounds and in 1963 138.3 million pounds. But both represented sizeable increases over the preceding year. In these years, beginning stocks and imports were too high for consumption rates, given the (assumed) randomness of landings. Thus, only in 1967 could the shrimp industry be called unlucky in the sense that the odds were against price drop of some magnitude.

Summary

The exogenous variables in the model all play a role in the determination of ex-vessel prices. The steady increase in imports from 1950 to 1968 has lowered the level of ex-vessel prices below what could have been expected in the absence of imports. A rough estimate from the model suggests that in the long run imports reduced the *increase* in ex-vessel price by about 60 percent. On the other hand, imports did not contribute greatly to annual price fluctuations, with the notable exception of 1959 when a large increase in imports accentuated the price decline caused by a large increase in landings.

Income increases (market expansion) caused ex-vessel prices to increase throughout the period, but the increases were less in the recession years of the period. Price declines caused by large increases in domestic landings in 1954, 1963, and 1967 were accentuated by a slowdown in the increase in income for those years; the 1959 decline was kept from becoming worse by a slight increase in income growth that year. Thus, income fluctuations affected only the rate at which ex-vessel prices increased and did not cause price decreases.

Domestic landings remain as the largest single source of price variation and, because landings cannot be forecast, the shrimp industry will have to contend with this source of variation for some time to come. But, as mentioned, price variations caused by landings were accentuated from time to time by fluctuations in the rate of increase of imports and income.

Any empirical endeavor can be improved and the present study is no exception. In particular, further study should be directed towards a domestic supply function. The business cycle dilemma pointed out above could then be resolved. Because imports now comprise the major source of supply, the import market deserves much closer scrutiny than it has received here. Finally, demand functions for the different forms in which shrimp are marketed would be a very helpful addition.

References

[1] BERRY, RICHARD J., "Dynamics of the Tortugas (Florida) Pink Shrimp Population," unpublished Ph.D. thesis, University of Rhode Island, 1967.

[2] CHRIST, CARL F., *Econometric Models and Methods*, New York, John Wiley & Sons, Inc., 1966.

[3] CLEARY, D., *Demand and Prices for Shrimp*, Working Paper No. 15, Division of Economic Research, Bureau of Commercial Fisheries, June 1969.

[4] DOLL, JOHN P., AND SEAN B. CHIN, "A Use for Principal Components in Price Analysis," *Am. J. Agr. Econ.* 52:591–593, Nov. 1970.

[5] FOOTE, RICHARD J., *Analytical Tools for Studying Demand and Price Structures*, USDA Agr. Handbook 146, Aug. 1958.

[6] GILLESPIE, WILLIAM C., JAMES C. HITE, AND JOHN S. LYTLE, *An Econometric Analysis of the U.S. Shrimp Industry*, AE 330, Department of Agricultural Economics and Rural Sociology, Clemson University, 1969, mimeo.

[7] GOLDBERGER, ARTHUR S., *Econometric Theory*, New York, John Wiley & Sons, Inc., 1964.

[8] HOUCK, JAMES P., "The Relationship of Direct Price Flexibilities to Direct Price Elasticities," *J. Farm Econ.* 47:789–792, Aug. 1965.

[9] OSTERBIND, CARTER C., AND ROBERT A. PANTIER, *Economic Study of the Shrimp Industry in the Gulf and South Atlantic States*, Gainesville, Bureau of Economic and Business Research, College of Business Administration, University of Florida, 1965.

[10] THEIL, HENRI, *Principles of Econometrics*, New York, John Wiley & Sons, Inc., 1971.

[11] U.S. Department of the Interior, *Report of the Secretary of the Interior to the President and the Congress on Fresh, Frozen and Processed Shrimp*, Washington, April 1960, mimeo.

[12] WILSON, ROBERT R., RUSSELL G. THOMPSON, AND RICHARD W. CALLEN, *Optimal Investment and Financial Strategies in Shrimp Fishing*, TAMU-SG-71-701, Sea Grant Program, Texas A&M University, Dec. 1970.

A Sequential Programming Model of Growth and Capital Accumulation of a Farm Under Uncertainty*

D. Yaron and U. Horowitz

Advantages of the sequential approach to making decisions under uncertainty are well known. However, the relatively detailed analysis involved, when applied to empirical problems, faces the "curse of dimensionality." In 1955 Dantzig offered a model of sequential programming under uncertainty which combined the merits of linear programming and sequential analysis. This paper presents an extension of Dantzig's model intended to reduce the dimensionality difficulty by introducing the distinction between long-run (primarily investment) and short-run (current production) planning. This paper also includes treatment of uncertainty in terms of eliminating plans which may lead to severe failures (bankruptcy) at any sequentially conceivable state over the planning horizon.

The advantages of the sequential approach to making decisions under uncertainty are well known. However, the relatively detailed analysis involved, when applied to empirical problems, faces what is called the "curse of dimensionality." Accordingly, it appears that this line of attack is primarily restricted to problems of "limited volume" such as real investment decisions [10] or partial analyses of specific problems [2]. Also, the nonsequential types of analysis such as optimal portfolio selection [12, 14] and risk analysis [9] are relatively widely used. In 1955 Dantzig [4] offered a model of sequential programming under uncertainty which combined the merits of linear programming and sequential analysis. However, in empirical analyses this model is heavily restricted by the dimensionality problem [1, 3, 13]. This paper presents an extension of Dantzig's model intended to reduce the dimensionality difficulty by introducing the distinction between long-run (primarily investment) and short-run (current production) planning. Another highlight in this paper is the treatment of uncertainty in terms of eliminating plans which may lead to severe failures (bankruptcy) at any sequentially conceivable state over the planning horizon.

General Framework

This paper presents a sequential programming model of growth and capital accumulation of a farm under uncertainty with the objective of maximizing its expected income over the planning horizon, subject to the restriction that risk of "failure" should be completely eliminated. In general terms, the entrepreneur faces two groups of activities: (a) activities with high income expectation and relatively high risk of failure, hereafter called "intensive activities," and (b) activities with low but relatively "safe" income, hereafter called "extensive activities." The ability of the entrepreneur to bear risk increases with the level of his equity, which is accumulated over the planning horizon. The essence of the problem is to determine, for each possible state of the farm at each stage of the planning horizon, the optimal mix of the intensive and extensive activities. This mix depends upon: 1) investment previously made in fixed productive assets of the farm; 2) "states of nature" previously materialized; 3) level of equity accumulated; and 4) future expectations. Such a problem falls within the framework of sequential programming.

Some general assumptions are presented below.

It is assumed that the farm operator is completely risk neutral above the level of "failure income," while at or below this level of income his utility is infinitely low. Denoting monetary income by X, "failure income" by $\underline{X}$, and utility by $u(X)$, the assumed utility function of the farm operator can be formally expressed as

$$u(X) = \begin{vmatrix} X, X > \underline{X} \\ -\infty, X \leq \underline{X}. \end{vmatrix}$$

With this information of the utility function the authors' approach combines elements of the conventional models which maximize the expected income with models which maximize the

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D. Yaron *is senior lecturer and* U. Horowitz *was a research assistant in agricultural economics at the Hebrew University of Jerusalem.* Horowitz *is presently a graduate student at Iowa State University.*

probability of exceeding a predetermined level of aspiration [7, 8].[1]

"Failure income" is defined as a state leading to lack of liquidity or bankruptcy, accounting for the possibility of borrowing capital and liquidating the liquid assets of the farm. It is assumed that the extensive activities provide for a solution which meets the nonbankruptcy restriction under all states of nature. In the concluding section of this paper the determination of failure income and alternative formulations are discussed in more detail.

The planning horizon is subdivided into T periods or years. It is assumed that the stages of development of the farm can be characterized by a limited number of structural variables such as capital accumulated, fixed assets of type A, and fixed assets of type B. The levels of these structural variables vary over the years of the planning horizon and provide for each year the framework for short-run production.

Accordingly, a distinction is made between long-run and short-run planning. The long-run planning is concerned with the structure of fixed assets and capital accumulation of the farm over the whole planning horizon. The short-run planning is concerned with the current production at any one of the T years, conditionally on the state of fixed assets of the farm and equity at the relevant year.

The distinction between short-run and long-run planning is essential to the application of multistage planning under uncertainty. Due to this distinction, the whole system is decomposed into a series of short-run plans bound together by the long-run plan. The short-run plans serve as activities in the long-run program and thus, compactness of the latter is achieved. As is known, it is generally preferable to solve numerous small programs to reduce considerably the size of a large program.[2]

Planning involves uncertainty and is built up from a succession of decisions or acts and random events. A corresponding decision tree for a planning horizon with $T=2$ is presented in Figure 1. The block nodes in Figure 1 represent the state of the system at any of the stages of the planning horizon with

SR_t^i = the ith short-run plan for year t, $(t=1, 2; i=1, 2, \cdots, I)$;

θ_t^j = the jth random event in year t, $(j=1, 2, \cdots, J)$;

$R_t | SR_t^i, \theta_t^j$ = the immediate return in year t, following the ith short-run plan and jth random event;

ξ_t^i = ith state of the fixed productive assets in year t;

ϕ_t^{ij} = ijth state of own investable capital at the end of year t following history ij.

It is assumed that any θ_t^j is independent of the preceding history and that the probability distribution of the events is constant over the planning horizon, i.e., $P(\theta_t^j | \theta_{t-1}^s) = P(\theta_t^j)$ for all j, s, and t.[3]

Empirical background

The model presented has been developed for a practical problem of planning a typical family farm in southern Israel (a "field crop farm" in the Negev). Such a farm is primarily involved in production of irrigated field crops. The technology of production is well established, irrigation eliminates weather uncertainty, and the prices are kept stable by government controls. Accordingly, there is little risk involved in production of these crops, and with no undue loss of reality this risk will be regarded as negligible. However, the income originating in this type of production is low and a way for intensification of production is sought. One line of intensification is a shift to production of out-of-season vegetables in plastic-walled houses.[4] This implies a relatively high investment and involves a risk of failure due to low selling prices. The problem of these farms is to determine the optimal rate of shifting to the intensive and risky production of the crops grown in the plastic houses (protected crops). Without going into more detail, this real life problem provides background for an empirical example of the model.

The model is of course applicable to numerous other problems concerned with farm growth under uncertainty: the fixed asset state vari-

[1] While models of the second group maximize the probability of exceeding the aspiration level, our model maximizes the expected income subject to the restriction that the probability of income below "failure" is zero for any conceivable state of events. Our formulation is similar to Ellsberg's [6] who suggested as an objective function P Minimax$+(1-P)$ Expected Value, $0 \leq P \leq 1$.

[2] The approach is similar to the decomposition algorithm in linear programming [5]. Note that divisibility of the short-run plans is assumed.

[3] The model permits other formulations such as different probability distributions in various years, dependence of probability of events in year t on the preceding history, etc.

[4] This is a useful substitute for glass houses. Future reference will use the term plastic houses.

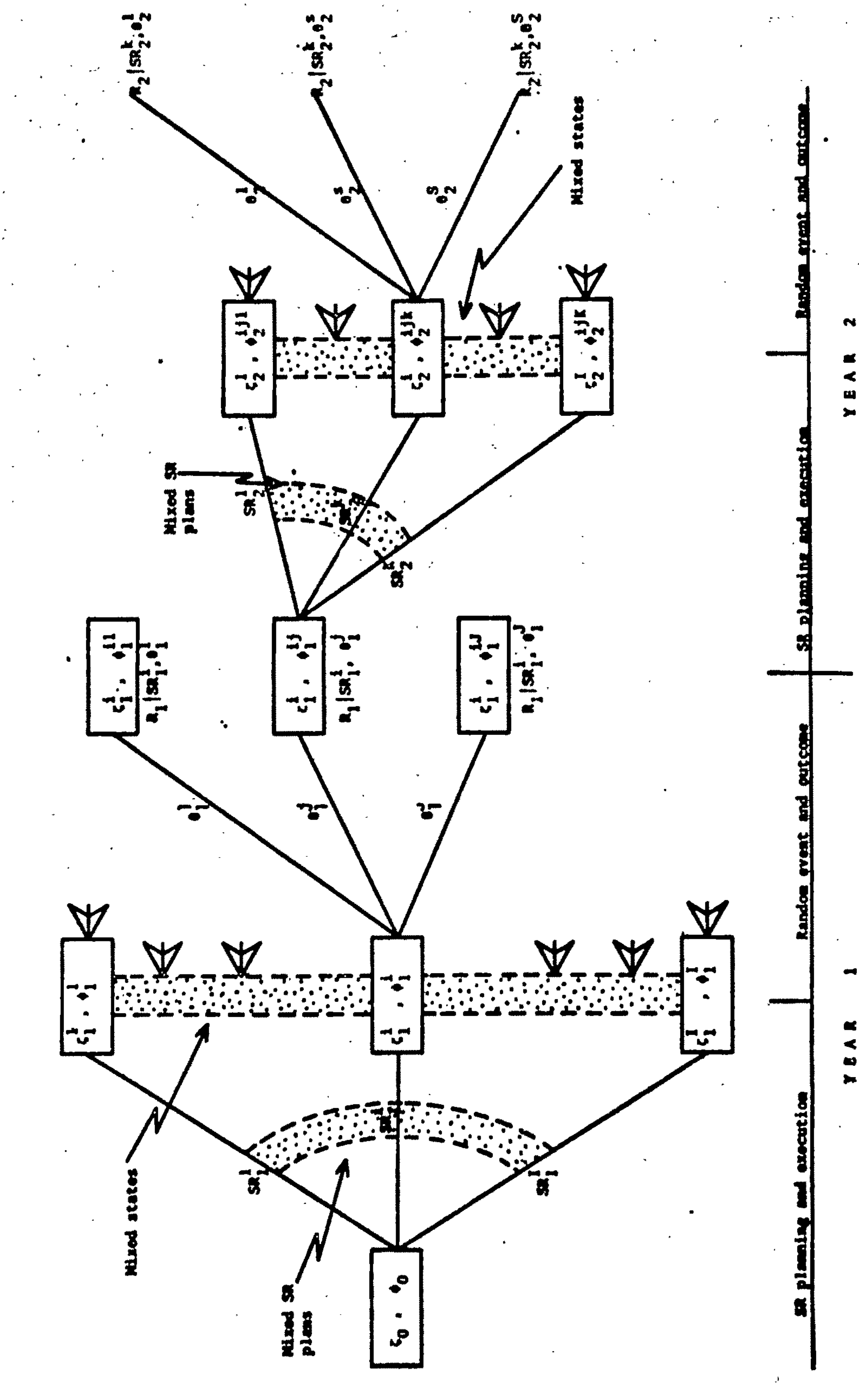

Figure 1. Decision tree presentation of the planning problem

ables (the long-run parameters) may be livestock, plantations, machinery, etc.

The model

Series of short-run plans.—For each year (a short-run planning period) several optimal short-run programs are solved. Any of the short-run plans takes into consideration:

a) A predetermined level of plastic house area;
b) Optimization of the remaining short-run production, i.e., field crops, subject to a), the availability of "natural resources" on the farm (land, water, and labor with investment capital excluded),[5] and the available technology;
c) The planning of field crops assuming a deterministic framework.

For each year in the planning horizon the number of the short-run plans equals the number of the predetermined discrete levels of plastic house area such as 0, 1, 2, 3, . . . area units.

Formally a t_ith short-run planning problem is stated as follows:

$$\text{(1)} \qquad \text{Maximize} \quad z_t^i = P_t Y_t^i$$

Subject to:

$$\text{(2)} \qquad \begin{array}{ll} G_t Y_t^i \leq B_t^i & t = 1, 2, \cdots, T \\ Y_t \geq 0 & i = 1, 2, \cdots, I \end{array}$$

where

z_t^i = the net return from the field crop production in the t_ith plan.
Y_t^i = the ith vector of levels of field crop activities in year t;
P_t = the vector of net returns per activity unit in year t;
G_t = the matrix of input coefficients in year t;
B_t^i = the vector of limited noncapital resources adjusted to the ith level of plastic house area in year t.

Solutions of the short-run plans for period t do not take into consideration the state of liquidity at the beginning of the year and indicate only the demand for investment capital to be incorporated in the long-run plan. Neither is the revenue of the protected crops, determined by the random event θ_t^j (at the end of the year t), considered in the short-run plans.

[5] Capital for current production is freely available due to existing short-term credit arrangements.

Random events and total returns from short-run plans.—At the end of any year t a random event θ_t^j with probability $P(\theta_t^j)$ determines the immediate net return r_t^{ij} of the ith short-run plan with

$$\text{(3)} \qquad r_t^{ij} = z_t^i + v_t^i \mid \theta_t^j$$

z_t^i = as determined by (1) and (2);
$v_t^i \mid \theta_t^j$ = net returns from the ith level of plastic house production in year t, given that the event θ_t^j has occurred (investment cost in plastic houses excluded).

The net return relationships are summarized in Table 1.

The long-run plan.—For relative compactness of presentation and with no loss of generality, the long-run planning model is presented for a two-year planning period, an opening state plus two states of nature in each year, and two short-run plans only for each year. The short-run plans are used as activities in the long-run program. They are assumed to be divisible and subject to mixing at various proportions. The long-run plan determines the optimal convex combination of the short-run plans for each year and their optimal sequence for any possible sequence of random events over the planning horizon. The optimization is restricted by 1) the availability of investment capital and 2) the nonbankruptcy requirement.

The periods comprising the planning horizon are indexed consecutively from 1 to 9 as follows:

1–3) Year 1: Opening, "Good", "Bad";
4–6) Year 2 after "Good": Opening, "Good", "Bad";
7–9) Year 2 after "Bad": Opening, "Good", "Bad".

With this indexing, the long-run planning

Table 1. Net return matrix for year t

State of nature / Short-run plan	θ_t^1	$\cdots$	θ_t^j	$\cdots$	θ_t^J
SR_t^1	r_t^{11}		r_t^{1j}		r_t^{1J}
$\vdots$	$\vdots$				
SR_t^i	r_t^{i1}	$\cdots$	r_t^{ij}	$\cdots$	r_t^{iJ}
$\vdots$	$\vdots$				
SR_t^I	r_t^{I1}		r_t^{Ij}		r_t^{IJ}

model is formulated mathematically in (4) and (5) below.

Maximize

$$
\begin{aligned}
f = {} & C_1X_1 + P_GC_2X_2 + P_BC_3X_3 \\
& + P_G(C_4X_4 + P_GC_5X_5 + P_BC_6X_6) \\
& + P_B(C_7X_7 + P_GC_8X_8 + P_BC_9X_9)
\end{aligned} \tag{4}
$$

Subject to:

$$
\left[\begin{array}{ccc|ccc|ccc}
A_{11} & & & & & & & & \\
A_{21} & A_{22} & & & & & & & \\
A_{31} & & A_{33} & & & & & & \\
\hline
 & A_{42} & & A_{44} & & & & & \\
 & & & A_{54} & A_{55} & & & & \\
 & & & A_{64} & & A_{66} & & & \\
\hline
 & & A_{73} & & & & A_{77} & & \\
 & & & & & & A_{87} & A_{88} & \\
 & & & & & & A_{97} & & A_{99}
\end{array}\right]
\times
\left[\begin{array}{c} X_1 \\ X_2 \\ X_3 \\ \hline X_4 \\ X_5 \\ X_6 \\ \hline X_7 \\ X_8 \\ X_9 \end{array}\right]
\leq
\left[\begin{array}{c} B_1 \\ B_2 \\ B_3 \\ \hline B_4 \\ B_5 \\ B_6 \\ \hline B_7 \\ B_8 \\ B_9 \end{array}\right] \tag{5}
$$

and

$$X_k \geq 0 \qquad k = 1, 2, \cdots, 9$$

where

C_k = the vector of income parameters in situation k;
X_k = the vector of activity levels in situation k;
P_G and P_B = the probabilities of states of nature of "Good" and "Bad", respectively ($P_G + P_B = 1$);
A_{sk} = matrices of input-output coefficients ($s, k = 1, 2, \cdots, 9$);
B_s = the restriction vector in situation s.

Essentials of the detailed structure of (4) and (5) are shown in the format of a simplex table (Table 2). There are nine column blocks and nine row blocks in the table according to the nine situations distinguished. The activities in the first column block in the table (Year 1, Opening) are as follows:

P_{11} = fixed cost during the first year;
P_{12} = construction of plastic house area unit;
P_{13} = lending of capital on a one year basis, with r rate of interest;
P_{14} = borrowing capital on a one year basis, with r^* rate of interest;
P_{15}, P_{16}, P_{17} = short-run plans SR_1^1, SR_1^2, and SR_1^3 activity units, respectively.

The activities in the second column block (Year 1, "Good") are:

P_{21}, P_{22}, P_{23} = short-run plans SR_1^1, SR_1^2, and SR_1^3 activity units, respectively;
P_{24} = transfer of capital to the Opening period of Year 2;
P_{25} = transfer of plastic house area unit to the Opening period of Year 2;
P_{26} = liquidating (and selling) of plastic house area unit.

Activities P_{31}—P_{36} in the third period (Year 1, "Bad") are equivalent to P_{21}—P_{26}, except to income parameters in the objective function and capital coefficients in restriction rows 2.4 and 3.4, respectively. Similarly, the activities in column blocks 4–6 and 7–9 in Table 2 are symmetrical to those in column blocks 1–3. The letter symbols in the table are defined as follows:

a—amount of own investable capital at the disposition of the farm at the opening of Year 1 (I.L.);
b—investment capital required for construction of one unit area of plastic houses (I.L.);
c—amount of fixed cost per year (I.L.);
d—amount of capital return, principal plus interest, at the end of Year 1, per one I.L. of capital lent ($d = 1 + r$);
d*—amount of capital reimbursement, principal plus interest, at the end of Year 1, per one I.L. of capital borrowed ($d^* = 1 + r^*$);
e, f, g—net returns (I.L.) from short-run plans SR_1^1, SR_1^2, and SR_1^3, respectively, when "Good" state of nature materializes;
p—capital returns (I.L.) due to liquidation of one unit of plastic house area;
h, m, n—net returns (I.L.) from short-run plans SR_1^1, SR_1^2, and SR_1^3, respectively, when "Bad" state of nature materializes.

With these definitions the meaning of the restrictions in Table 2 can be easily explained.

Table 2: Essentials of structure of the simplex table of the long run planning model

Period Index	Year No.	State of Nature	Restriction No.	P_0	Level	Type	Year No. 1, Opening	1, Good	1, Bad	2 After Good: Opening	Good	Bad	2 After Bad: Opening	Good	Bad
					Probability		1	P_G	P_B	P_G	$P_G P_G$	$P_G P_B$	P_B	$P_B P_G$	$P_B P_B$
					Income		C_1	C_2	C_3	C_4	C_5	C_6	C_7	C_8	C_9
							$P_{11} P_{12} P_{13} P_{14} P_{15} P_{16} P_{17}$	$P_{21} P_{22} P_{23} P_{24} P_{25} P_{26}$	$P_{31} P_{32} P_{33} P_{34} P_{35} P_{36}$						
							A_{11}								
1	1	Opening	1.1	Fixed cost	1	=	1								
			1.2	Opening Capital	a	≥	b 1 -1								
			1.3	Opening PH Area	0	≥	-1 0 1 3								
			1.4	SR Feasibility	1	=	1 1 1								
							A_{21}	A_{22}							
2	1	Good	2.1	SR_1^1 Plan	0	=	-1	1							
			2.2	SR_1^2 Plan	0	=	-1	1							
			2.3	SR_1^3 Plan	0	=	-1	1							
			2.4	Closing Capital	0	=	c -d d*	-e -f -g 1 -p							
			2.5	Closing PH area	0	=		0 -1 -3 1 1							
							A_{31}		A_{33}						
3	1	Bad	3.1	SR_1^1 Plan	0	=	-1		1						
			3.2	SR_1^2 Plan	0	=	-1		1						
			3.3	SR_1^3 Plan	0	=	-1		1						
			3.4	Closing Capital	0	=	c -d d*		-h -m -n 1 -p						
			3.5	Closing PH area	0	=			0 -1 -3 1 1						
								A_{42}		A_{44}					
4	2	Opening after Good	4.1	Fixed cost	1	=									
			4.2	Opening capital	0	=		-1							
			4.3	Opening PH area	0	≥		-1							
			4.4	SR Feasibility	1	=									
5	2	Good/G	5.1-5.5							A_{54}	A_{55}				
6	2	Bad/G	6.1-6.5							A_{64}		A_{66}			
7	2	Opening after bad	7.1-7.4						A_{73}				A_{77}		
8	2	Good/B	8.1-8.5										A_{87}	A_{88}	
9	2	Bad/B	9.1-9.5										A_{97}		A_{99}

The first restriction states that the fixed cost must be covered at the end of Year 1. The second and the third restrictions present the balance of capital and plastic house area, respectively, at the opening of Year 1. The fourth restriction defines convex combinations of the short-run plans SR_1^1, SR_1^2, and SR_1^3. Restrictions 2.1 through 2.5 refer to Year 1 when a "Good" state of nature materializes. Restrictions 2.1 through 2.3 present, respectively, transfers of SR_1^1, SR_1^2, and SR_1^3 from the Opening period to the "Good" period. Restriction 2.4 formulates the balance of capital at the end of Year 1, "Good", with any positive balance transferred to the Opening of Year 2 after "Good" (activity P_{24}). Similarly, restriction 2.5 formulates the balance of plastic house area with a possible transfer to Year 2 and/or liquidation.

Restrictions 3.1 through 3.5 are similar to restrictions 2.1 through 2.5 with proper changes in the coefficients to suit a "Bad" state of nature. Restrictions 4.1 through 4.4 are similar to 1.1 through 1.4. Further restrictions are a systematical repetition of the previous ones.

Note that activities P_{24} and P_{34} represent

transfers of the net capital balance from the end of Year 1 after "Good" and "Bad" events, respectively, to the Opening of Year 2. Since the level of these activities is bound to be non-negative, restrictions 2.4 and 3.4 which state the balance of capital at the end of Year 1 after the two possible events represent the minimal requirement on liquidity.[6]

The mathematical formulation of the problem is equivalent to Dantzig's [4] multistage linear programming under uncertainty. Proof of optimality of the solution is given by Dantzig. The optimal solution points out to the optimal decision at the Opening period of Year 1 and to the conditionally optimal sequence of decisions afterwards, according to the sequence of states of nature.

A numerical example

The model described has been applied to the analysis of the optimal rate of transformation of a capital extensive field crop farm to a capital intensive farm involved in production of out-of-season vegetables in plastic houses with the residual resources being allocated to the conventional field crops. While a detailed description of the empirical analysis falls beyond the scope of this paper, the background and the data of the empirical problem were used for the construction of this example.[7] It involves a farm with 35 dunams of irrigable land,[8] an allotment of 22,000 m^3 of irrigation water,[9] and family labor. Additional land can be rented on a yearly basis and labor hired on a daily basis. At the opening of the planning horizon the own investable capital of the farm amounts to I.L. 5,000. Additional capital can be borrowed on a yearly basis at an 8 percent rate of interest. Excess of own capital can be lent at 6 percent. The more profitable field crops are restricted by acreage allotments. A few other restrictions originate in crop rotation considerations; they will not be detailed here. Planning horizon of two years, three alternative short-run plans, and two states of nature in each year were assumed in the example.

Table 3. **Optimal short-run field crop plans with three alternative levels of plastic house area**

Short-run plan	SR_t^1	SR_t^2	SR_t^3
Area of plastic houses, du	0	1	3
Spring potatoes, du	12	12	12
Fall potatoes, du	2	0	0
Peanuts, du	12	12	12
Sugar beets, du	4	4	1
Canning tomatoes	4	4	4
Hired labor days[a]	5	31[a]	313[a]
Total net income, I.L.[b]	6,790	6,670	6,280

[a] The plans specify the monthly distribution of the hired labor. Hired labor days above 5 were charged to plastic house production.
[b] Gross return less variable cost in field crop production.

Short-run plans.—(a) *Field crops.* Three alternative short-run plans with three predetermined area levels of plastic houses were solved as regular linear programming problems (1) and (2) with variable right-hand side technique. Each short-run plan comprised 35 activities and 31 restrictions and was intended to maximize the (deterministic) net returns from field crops with the farm resources adjusted to the predetermined plastic house area.

It is assumed that neither the availability of natural resources of the farm (land, water, labor) nor the technology prices and management change during the two years of the planning period. Accordingly, the optimal short-run plans apply equally well to the two years of the planning period. The essentials of these plans are shown in Table 3.

(b) *Plastic house production, state of nature overall net returns.* Two "states of nature" were defined—"Good" and "Bad" with respective probabilities of .62 and .38. The payoff matrix which relates the overall net returns (field crops and plastic house production) of the farm to the states of nature is shown in Table 4.

The long-run program.—Part of the simplex table of the example problem in a numerical exposition corresponding to the first year is shown in Table 5. This is an exact numerical presentation of submatrices A_{11} through A_{33}. Submatrices A_{21} through A_{99} are a systematical

[6] In most cases only restrictions 3.4 will be meaningful, with 2.4 being redundant. Different attitudes toward risk can be expressed by varying the lower bounds on the levels of the transferring capital activities (such as P_{24} and P_{34}), and the corresponding changes in the long-run plans can be observed.

[7] The assumptions made are directly related to the empirical problem. Due to space limitations their rationale is not discussed.

[8] 1 dunam = 0.25 acre.

[9] 1000 m^3 = 0.81 acre-feet.

Table 4. States of nature and overall short-run returns[a]

Thousand I.L.		
State of nature	"Good"	"Bad"
Probability[a]	.62	.38
Short-run plan (plastic house area)		
None	6.8	6.8
1 du	18.0	8.6
3 du	36.6	8.5

[a] Gross return less variable cost.

repetition of A_{11} through A_{33}, and due to space limitations are not shown.

The long-run optimal solution is shown in Table 6. The block rows in the table refer to the three periods within each year—Opening, Good, and Bad. The block columns refer to the years in the sequence—Year 1, Year 2 after Good, and Year 2 after Bad. The table refers to four possible sequences of optimal decisions and events and should be read as explained below.

For the sequence Year 1, Opening and Good: Year 2 after Good, Opening and Bad: Borrow I.L. 11,900 (11.9 units of P_{14}), construct 2.16; PH units and execute 0.42 units of SR_1^2 plan

Table 6. The optimal solution of the long-run problem

State of nature	Activity	P_j	Year 1 Level	Year 2 after Good Level	Year 2 after Bad Level
Opening	Fixed cost	P_{11}	1	1	1
	Construction of PH	P_{12}	2.16	0.84	—
	Lending	P_{13}	—	3.50	—
	Borrowing	P_{14}	11.9	—	10.2
	SR_1^1 Plan	P_{15}	—	—	—
	SR_1^2 Plan	P_{16}	0.42	—	0.42
	SR_1^3 Plan	P_{17}	0.58	1	0.58
Good	SR_1^1 Plan	P_{21}	—	—	—
	SR_1^2 Plan	P_{22}	0.42	—	0.42
	SR_1^3 Plan	P_{23}	0.58	1	0.58
	Capital transfer	P_{24}	10.0	46.0	20.3
	PH area transfer	P_{25}	2.16	—	—
	Liquidating PH	P_{26}	—	3	2.16
Bad	SR_1^1 Plan	P_{31}	—	—	—
	SR_1^2 Plan	P_{32}	0.42	—	0.42
	SR_1^3 Plan	P_{33}	0.58	1	0.58
	Capital transfer	P_{34}	—	17.9	—
	PH area transfer	P_{35}	2.16	—	—
	Liquidating PH	P_{36}	—	3	2.16

and 0.58 of SR_1^3 plan. Allow for one unit of fixed cost (P_{11}) which provides I.L. 6,000, and transfer I.L. 10,000 to (10 units of P_{24}) the opening of Year 2 after Good.[10] In Year 2 construct I.L. 0.84 units of PH, lend I.L. 3,500, execute one unit of SR_1^3 plan. At the end of

[10] Return of the loan at the end of Year 1 is not shown in the solution. It is implied, however, by the coefficients of P_{14}.

Table 5. A numerical presentation of the upper left part of the simplex table of the long run planning - Submatrices A_{11} through A_{33}

		State of Nature			Opening							Good						Bad					
		Probability			1.0							.62						.38					
		Income, 000 IL.			0	-7.8	.06	-.08	0	0	0	6.8	18.0	36.6	0	0	3.9	6.8	8.6	8.5	0	0	3.9
		Income x Probability			0	-7.8	.06	-.08	0	0	0	4.2	11.2	22.7	0	0	2.4	2.6	3.3	3.2	0	0	1.5
State of Nature	Restriction No.		Level	Type	P_{11}	P_{12}	P_{13}	P_{14}	P_{15}	P_{16}	P_{17}	P_{21}	P_{22}	P_{23}	P_{24}	P_{25}	P_{26}	P_{31}	P_{32}	P_{33}	P_{34}	P_{35}	P_{36}
Opening	1.1	Fixed cost, units	1	=	1																		
	1.2	Opening capital, 000 IL.	5	≥		7.8	1	-1															
	1.3	Opening PH Area, units	0	≥		-1			0	1	3												
	1.4	SR Feasibility, du	1	=					1	1	1												
Good	2.1	SR_1^1 Plan, units	0	=					-1			1											
	2.2	SR_1^2 Plan, units	0	=						-1			1										
	2.3	SR_1^3 Plan, units	0	=							-1			1									
	2.4	Closing capital, 000 IL.	0	=	6		-1.06	1.08				-6.8	-18.0	-36.0	1		-3.9						
	2.5	Closing PH Area, du	0	=									-1	-3		1	1						
Bad	3.1	SR_1^1, units	0	=					-1									1					
	3.2	SR_1^2, units	0	=						-1									1				
	3.3	SR_1^3, units	0	=							-1									1			
	3.4	Closing capital, 000 IL.	0	=	6		-106	1.08										-6.8	-8.6	-8.5	1		-3.9
	3.5	Closing PH Area, du	0	=															-1	-3		1	1

Year 2 allow for one unit of fixed cost, liquidate 3 units of PH, and transfer I.L. 17,900 to the end of the planning period. Note that 0.42 units of SR_1^2 plan and 0.58 units of SR_1^3 plan imply that the short-run production of field crops is 12 du spring potatoes, 12 du peanuts, 4 du canning potatoes, and $0.42\times4+0.58\times1=2.26$ du of sugar beet (see Table 3). The table should be read in a similar way for other sequences.

Figure 2 shows in a concise way the farm situation and the major decisions for any of the four possible sequences of decisions and random events. The terminal own capital values for each sequence are shown at the four end forks. The value of the objective function is I.L. 33,700 in terms of expected gross return to investment of I.L. 5,000. Bankruptcy is avoided; at worst, with two Bad random events in a row the terminal value of capital is zero (i.e., the farm loses its I.L. 5,000 opening capital).

The real empirical problem was extended over a planning horizon of three years, with four short-run plans in each year and three random events per year. Its optimal solution provided results similar in nature and degree of details to those of the example here presented.

Uncertainty in field crop production.—The uncertainty in field crop production was considered negligible and the one-year cropping decisions assumed a deterministic framework. This was justified by the relatively low variability in the net income of the field crop farming (well-established technology, irrigation, stable prices) on the one hand, the low scale of financial operations on the other. On the basis of the available data the variability coefficient of net income of such farms is evaluated at 20–25 percent. If the expected net income $E(I)$ of the family field crop farm discussed in this paper

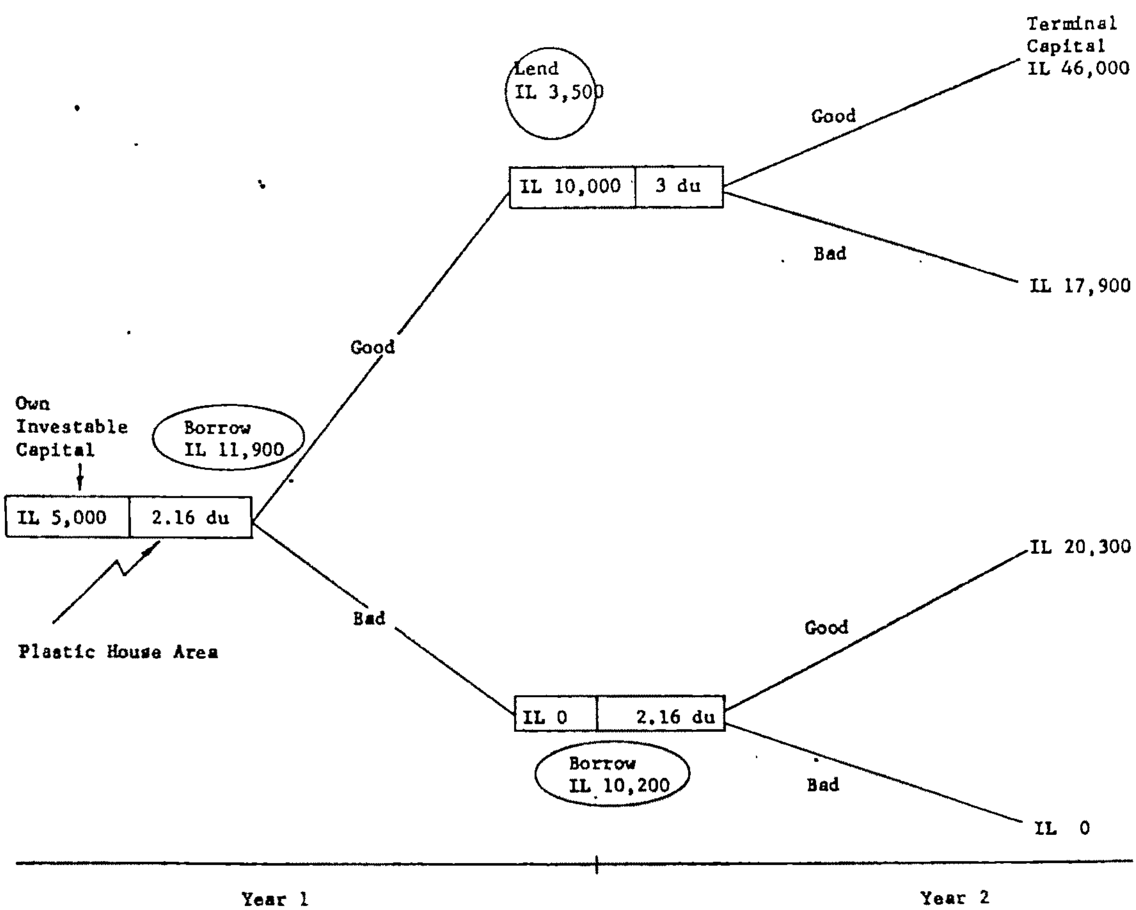

Figure 2. Graphical presentation of the essential results (rounded) of the optimal long-run program

is I.L. 6,800 and its standard deviation σ I.L. 1,700 (25 percent), an extremely unfavorable outcome of $E(I)-2\sigma$ leaves the farm family with a net income of I.L. 3,400 vs. fixed cost and consumption of I.L. 6,000. The gap can be closed, say, by a loan of I.L. 2,600, an amount which does not seem to risk its survival. On the other hand, uncautious expansion of plastic production may lead to disastrous levels of indebtedness and bankruptcy.

Concluding Comments

This paper presents a sequential programming model of growth of a farm and its capital accumulation under uncertainty. To overcome the dimensionality difficulty the model decomposes the long-run problem into a series of short-run problems, bound at a later stage into a master long-run problem. The decomposition applied is a simplification of the decomposition algorithm of Dantzig and Wolfe [5]. Their algorithm, if applied to this problem, would have generated a loop consisting of solution for a set of short-run plans, their incorporation into the long-run plan, derivation of shadow prices of the long-run restrictions, solving for a second set of short-run plans, and so forth up to the convergence of the optimum solution. This "quasi decomposition" approach determines at once a number of short-run plans sufficient to generate in an approximation the whole space of short-run solutions, while the long-run optimal solution determines the optimal convex combination of the short-run solutions. The authors' approach avoids the looping of the decomposition principle at the cost of providing only an approximate optimum. The solution can be brought to any desired degree of approximation by increasing the number of the short-run plans and their refinement.

For the purpose of the model presented here, failure level of income was determined as a state leading to bankruptcy or lack of liquidity at the end of any of the years over the planning horizon. However, in certain empirical situations safety from bankruptcy may not be achievable; in other situations the criterion of avoiding bankruptcy as a permissible lower bound for failure may be too liberal. Sensitivity analyses may be helpful to the entrepreneur in the determination of his aspiration level in terms of failure income. Solving long-run problems (4) and (5) parametrically with respect to the closing capital restrictions may reveal (a) the non-achievable aspiration levels and (b) the substitution relationships between the achievable aspiration levels for each period and the value of the objective function. Such analysis may aid the entrepreneur in choosing the long-run plan.

Regarding the computations involved, the empirical problem solved did not pose any difficulties. The short-run plans each comprised 35 restrictions and 31 activities. Numerous parametric linear programming solutions of such a problem (and of quite larger problems) require computer time amounting to a few minutes. The long-run program of the empirical analysis, which is only briefly mentioned in the previous section, extended over three years of the planning horizon with three states of nature per year. The corresponding linear programming problem comprised 275 restrictions and 330 activities; the solution time on a CDC 6400 computer was six minutes. On the other hand, preparation of the input data is a relatively cumbersome process. To overcome this difficulty a routine for a mechanized generation of a computer input can be used. Such a routine is a part of the OPTIMA system for linear programming on a CDC 6400 computer.

It should be noted that the same general problem may be solved through application of (Bellman's) dynamic programming. In effect the second approach is necessary when the short-run plans are not divisible. Still another approach based on integration of linear programming and decision tree analysis has been applied by the authors [11]. The relative merits of the alternative approaches should be judged in terms of the computational effort involved, the information provided, and their susceptibility to parametric solutions and sensitivity analyses. Additional experience is needed in order to evaluate and compare them fully.

References

[1] AMIAD, A., AND D. LAMDAN, *Two Stage Programming Under Uncertainty*, Department of Agricultural Economics, Hebrew University of Jerusalem, 1967, mimeo (in Hebrew).

[2] BURT, OSCAR R., AND RALPH D. JOHNSON, "Strategies for Wheat Production in the Great Plains," *J. Farm Econ.* 49:881–899, Nov. 1967.

[3] COCKS, K. D., "Discrete Stochastic Programming," *Mgt. Sci.* 15:72–79, Sept. 1968.

[4] DANTZIG, G. B., "Linear Programming Under Uncertainty," *Mgt. Sci.* 1:197–206, 1955.

[5] ———, AND D. WOLFE, "The Decomposition Algo-

rithm for Linear Programming," *Oper. Res.* 8:101–111, 1960.

[6] ELLSBERG, DANIEL, "Risk, Ambiguity and the Savage Axioms," *Quart. J. Econ.* 75:643–669, Nov. 1961.

[7] GEOFFRION, ARTHUR M., "Stochastic Programming with Aspiration or Fractile Criteria," *Mgt. Sci.* 13: 672–679, May 1967.

[8] HANSSMANN, F., "Probability of Survival as an Investment Criterion," *Mgt. Sci.* 15:33–48, 1968.

[9] HERTZ, D. B., "Risk Analysis in Capital Investment," *Harvard Bus. Rev.* 42:94–106, 1964.

[10] HESPOS, RICHARD F., AND PAUL A. STRASSMANN, "Stochastic Decision Trees for Analysis of Investment Decisions," *Mgt. Sci.* 11:B244–B259, Aug. 1965.

[11] HOROWITZ, U., "A Model for Sequential Programming of a Family Farm Under Uncertainty," unpublished M.Sc. thesis, Hebrew University of Jerusalem, 1970.

[12] MARKOWITZ, HARRY MAX, *Portfolio Selection, Efficient Diversification of Investments*, New York, John Wiley & Sons, Inc., 1959.

[13] RAE, ALLAN N., "An Empirical Application and Evaluation of Discrete Stochastic Programming in Farm Management," *Am. J. Agr. Econ.* 53:625–638, Nov. 1971.

[14] SALAZAR, R. C., AND S. K. SEN, "A Simulation Model of Capital Budgeting Under Uncertainty," *Mgt. Sci.* 15:B161–B179, 1968.

Projections of Effects of Modern Inputs on Agricultural Income and Employment in a Community Development Block, Uttar Pradesh, India*

IAN R. WILLS

While the green revolution has increased food production, its effects on rural employment and income distribution are causing concern. This paper presents empirically based estimates of the impact of new technology on employment and incomes at the local level. Results indicate that although adoption of new seeds, fertilizers, and irrigation increases employment and agricultural wages, it also increases the disparity between incomes of farmers and agricultural laborers, a disparity which will increase further if labor-saving machinery is introduced. New technology will reduce the disparity between incomes of large and small farmers if credit and fertilizers are distributed according to area operated.

MODERN agricultural inputs, having become generally available in recent years, are now widely adopted in India. Utilization of high-yielding crop varieties, chemical fertilizers, herbicides, pesticides, and privately owned pumping equipment has caused substantial increases in food production, especially in the wheat-growing areas of northern India. In 1970–71 Indian wheat production totaled 23.2 million metric tons, compared to 12.3 million tons in 1964–65 and 16.6 million tons in 1967–68.

However, the success of this new agricultural technology may have its drawbacks. A number of observers are concerned about the possible effects of the new technology on agricultural employment and on the relative incomes of the various groups dependent on agriculture for their livelihood [5, 12]. There is also speculation on the appropriateness of extensive agricultural mechanization (particularly the introduction of farm tractors) in an economy characterized by a relative shortage of modern capital, the dependence of a large proportion of the work force on agriculture, and a rapid rate of increase in the rural population [3, 4, 8].

The purpose of this paper is to report the results obtained when a linear programming model of crop production was used to estimate the likely effects of widespread adoption of the new technology on agricultural employment and incomes in a single Community Development Block in Western Uttar Pradesh.[1]

Method

The prediction model is based on four assumptions about the future availability and adoption of new technology: (1) the new inputs widely available to study-area farmers in 1968 (high-yielding crop varieties, chemical fertilizers, and modern pumping equipment) will be generally adopted within five years; (2) farmers will adopt the new inputs as fast as they are made available by suppliers; (3) no other modern inputs will be widely adopted by farmers within five years; and (4) the farmers who made extensive use of the new inputs in 1968 are representative of all farmers five years later.

Assumptions are also made about future supplies of such important agricultural inputs as labor, irrigation water, chemical fertilizers, animal power, and operating capital and about future input and product prices. Alternative government policies are anticipated by varying the future availabilities of modern inputs. Implications of the total set of assumptions are determined using a linear programming model to represent the crop production situation within the study area at the end of the five-year period.[2] The model incorporates programs for

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IAN R. WILLS *is lecturer in agricultural economics at Monash University, Clayton, Victoria, Australia.*

[1] The Community Development Block is the smallest comprehensive developmental unit in the Indian planning structure. Each block covers approximately 100 villages and is supposed to have a full complement of specialists dealing with all technical aspects of agricultural development, plus its own allocation of publicly supplied agricultural inputs such as chemical fertilizers, new seeds, pesticides, and credit.

[2] A recursive programming model of the type employed by Singh [7] to analyze past technological change would permit specification of the adjustment processes occurring within the five-year period. The choice of a single-period model was dictated by a lack of information on consumption and investment activities and by the assumption that rates

"representative" farms of different sizes so that the solutions yield information about the impact of new technology on different sized farms.

The Bisauli Community Development Block in the Budaun district of Western Uttar Pradesh was chosen for the study. Estimates of future crop yields, rates of input use, and availabilities of farm-supplied inputs were collected in interviews with farmers in June and October of 1968[3] and from data gathered by the agricultural extension service of Uttar Pradesh Agricultural University. All of the farmers interviewed had used the new agricultural inputs extensively in 1967 and 1968; technical data from these farms were assumed to be representative of all Bisauli-area farms in 1972–73.

Evidence on the Process of Technological Change

The assumptions concerning the future availability and adoption of new technology are supported by the results of the field investigations in the Bisauli area.[4] With respect to the availability of modern inputs, it was found that public agencies effectively control the availability of chemical fertilizers, electrical power for pumping units, and medium and long-term credit in the Bisauli area, as well as the availability of additional modern inputs such as new crop varieties and farm tractors. These findings provide a basis for the model's assumptions of input fixity and static technology. Furthermore, given the high degree of complementarity between components of the new agricultural technology, it follows that the availability of publicly supplied fertilizers, electric power, and credit sets the maximum rate of adoption of modern inputs.

Interviews with survey farmers supported the assumption that the new inputs are adopted as fast as they are made available. A number of farmers reported difficulties in obtaining chemical fertilizers, while others experienced delays varying from a few months to a year in obtaining credit and electric power connections.

The adoption rates of modern agricultural inputs in the study area were particularly high after high-yielding varieties were introduced in 1966 (Cf. Table 1). Adoption was not confined to the large farms, the better educated farmers, or to a minority of villages in the block. Farm interviews indicated that the relatively widespread use of new technology as early as 1968 was due largely to two features of technological change in the Bisauli area: (1) the new inputs in use in 1968 did not substantially change the conduct of regular crop operations and hence did not cause major managerial problems; and (2) a widespread market for privately pumped water existed, giving small farmers access to modern pumping equipment. These findings suggested that rapid adoption of modern inputs would continue after 1968.

The Model

The particular linear programming model used was derived from those suggested by Yaron, Plessner, and Heady [14] and Swanson [9]. The model is a single-period linear programming problem incorporating three types of farms and three categories of fixed inputs. Maximization of the objective functions for individual farm types is subsumed in the maximization of the objective function for the study area as a whole.

Three types of farms incorporated into the model accounted for the major variations in farm size in the Bisauli block. Individual farms within the block were aggregated into three size groups assumed homogeneous with respect to possible activities, input constraints, input-output coefficients, and prices. It was assumed

Table 1. Levels of use of modern agricultural inputs in the Budaun district, 1961 to 1968

	1961–62	1965–66	1966–67	1967–68
Area sown with high-yielding wheat (acres)			5,755	57,420
Area sown with other high-yielding food-grains (acres)			889	9,541
Quantity of nitrogenous fertilizers distributed (metric tons)	3,110	8,471	7,892	14,484
Number of privately owned pumping installations at the end of the year	252	719	1,550	2,796

Source: Unpublished data supplied by the Uttar Pradesh State Directorate of Economics and Statistics, Lucknow.

of adoption are determined by supply rather than demand factors.

[3] This study uses data from two interview surveys conducted in the Bisauli block. The first was conducted by a team of investigators from the Uttar Pradesh Agricultural University [10]. The second, conducted by the author, involved follow-up interviews with 30 of the farmers from the first survey and included interviews specifically designed to obtain information about labor use on crop-wise and operation-wise bases.

[4] For a detailed account of the survey procedure and the information obtained, see [13].

that every farmer in a given group would choose exactly the same cropping pattern; the resource supplies and output for the group were those of the individual "representative" farm in the group multiplied by the number of farms in the group [14, p. 66]. Aggregation of individual farms into homogeneous size groups was based on cultivated area, with the size distribution of holdings assumed fixed.

The three categories of fixed inputs included in the model are (1) inputs fixed at the farm level and not transferable to other farms; (2) inputs fixed at the farm level which are transferable (via a selling/purchasing activity) to other farms; and (3) inputs fixed only at the area level which are available (via a purchasing activity) to all farms. Cultivated land, family and permanent hired labor, publicly supplied irrigation water, and operating capital comprise the first category. Privately pumped irrigation water, assumed to be produced only on large farms and to be salable to all types of farms, is in the second category. Chemical fertilizers and casual labor are in the third category of fixed inputs.

In the model those inputs fixed in quantity at the farm level are automatically fixed for each farm size group. The inputs fixed at the area level are allocated among farm size groups according to marginal productivity principles, since the objective function being maximized applies to the study area as a whole and not to single farms or groups of farms.

The activities, constraints, and objective function of the model are now briefly described.[5]

Activities

The model includes three sets of activities for each farm size group: crop production activities, input transfer activities, and input disposal activities. Input transfer activities involve between-farm transfers of privately pumped irrigation water and transfers of casual labor from an area labor pool to augment farm labor supplies. The input disposal activities allow farmers to employ their operating capital in areas other than crop production.

The set of crop production activities in the model is restricted to crops grown on the survey farms; no other agricultural enterprises are important in the survey area. Crop activities include crops grown in the monsoon (*kharif*) and the winter (*rabi*) seasons and both the older indigenous crop varieties and the new high-yielding ones.[6] In the case of the high-yielding varieties, only a single level of technology, involving moderately heavy applications of chemical fertilizers and irrigation water, is represented for each crop. Indigenous varieties (those which are more responsive to chemical fertilizers and/or irrigation) such as rice, wheat, peas, gram, peanuts, and sugarcane are represented by two activities. This allows a choice between growing the crop under "traditional" technology with no chemical fertilizers and little or no irrigation water or under "improved" technology with moderate levels of fertilizers and irrigation water.

Constraints

The model includes two types of constraints—consumption and resource. The consumption constraints are designed to ensure the provision of certain minimum quantities of cereals for home consumption and dry fodder for farm animals. The resource constraints represent availabilities of two qualities of land, family and permanent hired labor, casual hired labor, publicly and privately supplied irrigation water, chemical fertilizers, and operating capital in the Bisauli block in 1972–73.[7] In the case of inputs fixed at the farm level there are separate constraints for each of the three farm size groups. The constraints for land, labor, and irrigation water are further subdivided on a seasonal basis to allow for the marked seasonality of input use and the variety of multiple-crop combinations characteristic of agriculture throughout northern India [2].

The objective function

Area farmers are assumed to maximize annual profits from crop production subject to the consumption and resource constraints imposed in the model. All product and input markets are assumed perfectly competitive and farmers' price and yield expectations are assumed to be single-valued.

Data

Yields and input requirements for the various crop activities were obtained from survey farms

[5] For a detailed exposition of the model, see [13].

[6] The high-yielding crop varieties included in the model were hybrid corn, hybrid millet, and high-yielding varieties of rice, "Mexican" wheat, mustard, and potatoes.

[7] Bullock power is not explicitly included in the model. Bullock power requirements parallel those for human labor, and calculations based on the survey data indicated that human labor limits the expansion of crop production before bullock power.

and agricultural extension workers. Based upon survey evidence, it was assumed that mean yields and levels of input use for each crop activity were the same on each type of farm.

Both the size distribution of holdings and the labor force data used in the model are based on the 1961 Census of India. Farms are aggregated into three size groups which contain "representative" farms of 20, 8, and 3.2 acres.[8] Population growth projections for the Uttar Pradesh state and past population growth statistics for the Budaun district are combined with the census data to project the maximum number of persons available for crop production work in 1972–73. In the cases of irrigation water, chemical fertilizers, and operating capital, where government policies may affect the future availability of supplies, the model is solved for alternate availabilities of the inputs.

The product prices used are 1968–69 harvest season prices from the Bisauli area;[9] the input prices are also those prevailing in the area in 1968–69. However, the 1968–69 prices are not necessarily equilibrium prices in the cases of casual labor and privately pumped water where the total supply available in the block is fixed and the input in question is not administratively priced and is transferable between farms. In the programming solutions which provide the following results, equilibrium wages and equilibrium water prices are determined by altering the assumed price and resolving the model until the assumed price equals the price implied in the programming solution.

Results

The linear programming model is used to calculate optimum cropping patterns for six future situations incorporating two levels of fertilizer availability and three levels of operating capital availability.[10] The results are presented here in the form of averages over the six solutions. Table 2 shows the average cropping pattern and crop production derived from the six solutions, plus the assumed yields of major crops, and compares them to the cropping pattern, crop production, and yields recorded for the Budaun district in 1967–68. The model predicts an increase in overall cropping intensity and large increases (113 percent for foodgrains and oilseeds and 174 percent for sugarcane) in output for all major categories of crops during the period 1967–68 to 1972–73. The predicted product mix shows a shift away from wheat in favor of monsoon season cereals and winter pulses.

The results in Table 2 almost certainly overestimate the increase in monsoon season cereals because net returns above assumed costs of hired labor and operating capital for native corn and native rice are so small that farmers would lose very little revenue by sowing less than the predicted crop area. Comparing this revenue loss to the extra managerial effort required to handle a larger crop area, farmers will probably not consider it worthwhile to grow as much monsoon season cereals as the results suggest. However, all winter crops show substantial net returns above assumed costs, so it appears that farmers will want to sow the maximum area possible in the winter season.

Table 3 gives the monthly pattern of crop labor demand and wages derived from the programming solutions and compares them to 1967–68 data for the Budaun district. The monthly pattern of labor demand in 1967–68 is estimated by applying the labor requirements coefficients used in the programming model to 1967–68 crop statistics in Table 2. These results are discussed in the following section dealing with employment and wages.

Table 4 gives the average cropping patterns on large, medium, and small farms and the gross and net incomes per acre from crop production obtained by large, medium, and small farmers. Under the assumed allocation of operating capital and with fertilizer allocated between farms according to the marginal value productivity on each type of farm, the predicted net returns per acre from crops alone are 40 percent higher on small farms than on medium farms, and 16 percent higher on medium farms than on large farms. When returns from predicted sales of pumped water by large farmers are added, per-acre net returns on large farms are equal to those on medium farms.

Implications for Employment and Wages

From the results in Table 3 it seems certain that adoption of new agricultural technology

[8] Farms of under two acres are not represented in the model since they comprise only 5 percent of the block's cultivated area.

[9] Prices for 1968–69 are used because such projections of future agricultural production as were available at the time of the study suggested that foodgrain supplies were unlikely to exceed demand in the near future [6]. Prices for 1968–69 reflect this sort of situation.

[10] Only a single level of irrigation capacity was considered. Within the range of input availabilities considered, chemical fertilizers and operating capital always limited crop production before irrigation water.

Table 2. Average area and production of crops predicted for Bisauli block in 1972–73, compared to crop statistics for Budaun district in 1967–68

Crop	Bisauli block 1972-73 Area	Bisauli block 1972-73 Production	Bisauli block 1972-73 Assumed Yields	Budaun district[a] 1967-68 Area	Budaun district[a] 1967-68 Production	Budaun district[a] 1967-68 Estimated Yields
	percent of crop land	metric tons per 1000 acres cultivated	kg per acre	percent of crop land	metric tons per 1000 acres cultivated	kg per acre
Monsoon season cereals						
Hybrid corn			900	0.3	23	280
Native corn	43.0	194	450	8.0		
Hybrid millet	5.5	50	900	0.4	40	175
Native millet			350	22.6		
High-yielding rice[b]			530	0.3	28	355
Native rice[b]	8.6	25	290	7.6		
Winter cereals						
High-yielding wheat	16.3	179	1,100	5.6	162	490
Native wheat	14.5	77	530	27.5		
Other cereals				5.8	12	
Monsoon season pulses				0.3	0.5	
Winter pulses	40.9	189		34.3	74.5	
Total foodgrains	128.8	714		112.7	340	
Oilseeds	21.8	81		13.2	38	
Sugarcane	8.6	1,260	14,700	2.7	460	17,000
Other crops				1.6		
Total, all crops	159.2			130.2		

[a] Source: [11, Tables 3.3 and 3.4]
[b] Production and yields in terms of cleaned rice

will substantially increase annual crop labor requirements. The model predicts a 57 percent increase in labor requirements in the Bisauli block between 1967–68 and 1972–73, which is probably an overestimate. As noted previously,

Table 3. Time-pattern of labor demand and wages predicted for the Bisauli block in 1972–73, compared to the Budaun district in 1967–68

	1972-73 Labor Demand (man-days/month/1000 acres)	1972-73 Wages (Rs/day)	1967-68 Labor Demand (man-days/month/1000 acres)	1967-68 Wages (Rs/day)
Months				
May–August	4,700	3.0	2,900	3.0
September	7,800	3.0	4,500	3.0
October	10,700	12.0	8,900	4.0
November	10,700	8.0	7,100	4.0
December–March	5,000	3.0	1,900	3.0
April	10,900	4.0	10,700	7.0
Average per month	6,600	4.25	4,200	3.50

Table 4. Average cropping patterns and returns per acre predicted for three sizes of farms in 1972–73

Crop	Type of Farm: Large	Medium	Small
	Percentage of Crop Land		
Native corn	33.6	46.0	47.0
Hybrid millet	13.2	4.4	
Native rice	15.2	6.2	5.8
High-yielding wheat	12.8	18.0	16.7
Native wheat	33.0	5.1	12.5
Winter pulses	33.0	50.2	32.1
Oilseeds	9.2	27.1	25.0
Sugarcane	4.0	7.6	15.4
	Rupees per Acre		
Gross crop returns	709	761	861
Returns net of harvesting and operating capital costs[a]	394	456	641
Returns from water sales	75		
Overall net returns	469	456	641

[a] These figures overstate annual net returns from crop production insofar as they neglect land rents, animal feed costs, and equipment maintenance costs directly due to crop enterprises.

the results almost certainly overestimate the increase in monsoon season cereals and likewise the increase in crop labor requirements. Evidence supporting a lesser increase in labor requirements was obtained from some of the survey farms. On 10 farms where pumping units had been installed before 1967–68, the per-acre use of human labor in 1967–68 averaged 35 percent higher than the labor use reported in the crop year immediately preceding installation of the pumping equipment.

In interpreting Table 3 it is necessary to take into account biases in the estimates of 1967–68 labor requirements. Application of the model's labor-use coefficients to the 1967–68 district cropping pattern leads to conflicting biases. On the one hand, the 1967–68 labor requirements should be higher because of the widespread use of older, more labor-intensive irrigation techniques. On the other hand, they should be lower because 1967–68 crop yields (and hence harvest labor requirements) in the Budaun district were lower than those assumed in the model. The net effect of these biases is too small to affect the conclusion that new technology will substantially increase crop labor requirements.

There is a marked divergence between the October-November and April (1967–68) wages reported in the Bisauli area and the wages predicted by the model for the same months in the future, i.e., an increase in the October-November wages and a decrease in the April wages in the future, relative to wages in 1967–68 (see Table 3, columns 2, 4). This divergence in wages requires explanation.

The very high October wage predicted for 1972–73 is probably spurious. The bulk of the October labor is used to harvest native corn and should the native corn acreage be less than predicted (as suggested earlier), the October wage will be substantially lower. The increase in November wages is associated with the widespread adoption of "Mexican" wheats. Because of its later sowing date and need for heavy doses of fertilizers and irrigation, introduction of "Mexican" wheat increases November labor requirements, which are increased still more when the wheat is combined with a peanut crop also requiring large amounts of November labor.

The decrease in April wages is also related to the introduction of "Mexican" wheats whose higher grain yields and lower straw-to-grain ratios, when compared to native wheat, mean less time and effort are necessary to harvest Mexican wheat. However, the low April wage predicted by the model does not reflect the importance of timeliness in the wheat harvest. In practice, the wages of casual labor may be bid up because each farmer wants to harvest the wheat crop as soon as it is ripe since there is always a danger of loss due to wind or rain. Taking the above factors into account, wages in October, November, and April, while remaining well above wages in other months, will probably be more nearly equal than the model predicts.

Due to the uncertainty about the size of the agricultural labor force in 1972, the model was solved assuming alternative rates of growth for the crop production work force between 1961 and 1972. Results from the alternative solutions show that changes of about 10 percent in the total available casual labor supply have relatively small effects on annual crop labor requirements and on the overall level and seasonal pattern of wages. Thus, it appears that the above predictions of future employment and wages are supported even if the estimate of the future labor supply is significantly in error.

Implications for Agricultural Incomes

The effect of increased crop production on farmers' incomes is difficult to estimate because of a lack of reliable information about average returns from crop production in 1967–68. In the survey of Bisauli-area farmers conducted by the Uttar Pradesh Agricultural University it was found that gross crop returns for 1967–68 averaged about Rs. 200 per acre for "average" farmers and Rs. 450 per acre for "progressive" farmers [10, Vol. II]. Alternatively, application of 1967–68 harvest prices to the 1967–68 crop production statistics for the Budaun district yields a gross return of Rs. 340 per acre for the district as a whole. Comparing these results to the gross returns in Table 4, the model predicts that farmers' gross returns from cropping will at least double between 1967–68 and 1972–73.

The data on net returns from cropping in 1967–68 are less satisfactory than those on gross returns. However, based on the university's survey results, it appears that the net returns predicted for 1972–73 are more than double the average net returns received by farmers in 1967–68.

Of significant interest is the higher per-acre crop income predicted for small (predominantly subsistence) farmers. The coming of the new technology has freed the small farmer from the

less profitable cropping patterns on which he could always depend to provide minimum quantities of such staples as wheat and animal fodder for home consumption. If he grows high-yielding varieties, the small farmer can supply his home consumption needs and still have land remaining to grow high-yielding cereals for market or other high-profit crops like sugarcane. If the minimum cereal and fodder constraints included in the model have counterparts in the real world, then in this respect the new technology is not neutral with respect to farm size.

The income advantage predicted for small farms by the model is, of course, conditional on the assumption that fertilizers are allocated between farms according to marginal value productivity. In these circumstances the predicted rate of fertilizer use falls with increasing farm size. If, on the other hand, the small farmers get lesser quantities of fertilizers, their crop incomes will fall relative to those of the large and medium farmers, and they will not enjoy the advantage predicted by the model.[11]

Incomes of agricultural laborers are determined by wages and the amount of employment obtained. Some casual laborers will be employed virtually year-round as are the permanent laborers on large farms. With real wages (in terms of 1968 prices) in 1967–68 and 1972–73 at the levels given in Table 3, the average real wage over the whole year for such persons would rise from about Rs. 3.50 per day in 1967–68 to Rs. 4.25 per day in 1972–73, a 21 percent increase in real income over the period if all else remains constant.

Clearly, high wages in two or three months do not cause great increases in the annual incomes of agricultural laborers. The problem encountered in estimating the impact of increased crop labor requirements on the incomes of agricultural laborers is to determine what percentage of the additional labor requirements will be met by the permanent labor force on farms and what percentage by the casual labor force. According to the model's assumptions, casual labor is hired for crop production activities on each farm only after the permanent labor force is fully employed in crop production. As a result, none of the solutions require any hiring of casual labor for crop production in the periods May through August and December through March. However, considering the rise in crop labor requirements in the off-peak periods predicted in Table 3, there will probably be considerably more casual employment in these periods.

The model assumes that the size of the permanent labor force on farms in the block remains constant between 1967–68 and 1972–73 and that the number of casual workers increases 21 percent. Given these assumptions, plus the labor requirements and wages in columns 1 and 2 of Table 3, the average casual worker's annual income from crop production activities will rise from 274 rupees in 1967–68 to 547 rupees in 1972–73. Therefore, the average casual agricultural laborer will receive about twice as much income from crop production activities in 1972–73 as he received in 1967–68. The increase will be somewhat greater if his employment expands as an indirect result of the increased crop labor requirements in the periods May-August and December-March. Clearly, his total annual income will remain, for the most part, dependent on his earnings in the 8 or 9 months during which his employment opportunities depend on the amount of agricultural activity other than cropping and on non-agricultural activity, plus any earnings from enterprises of his own.

These results suggest that while the widespread adoption of new technology will increase the real incomes of agricultural laborers who own no land or only tiny plots of land, their incomes are likely to fall relative to farmers' incomes (except for a fortunate few who possess special technical skills useful in the new technology, e.g., persons who have mechanical aptitude or training). In the extreme case of a farmer who earns practically all his income from cropping versus a landless laborer permanently employed on a farm, the relative shift would be quite drastic, since the farmer's real income would increase at least 100 percent over five years and that of the laborer only 21 percent.

The above discussion does not allow for the replacement of human labor by machinery, except for privately owned pumping equipment. However, high wages paid at harvesting and sowing times will prompt the owners of large holdings to invest in additional mechanical equipment—tractors, power tillers, power-driven threshers—which can substantially replace human labor [1]. The results presented

[11] In order to test the effects of redistributing fertilizers between farms, the model was solved assuming the same per-acre availability of fertilizers on all sizes of farms. Net crop returns on small farms were reduced as a result of reducing the allocation of fertilizers to small farms but still exceeded those on large and medium farms by more than Rs. 100 per acre.

here suggest that widespread adoption of such equipment by the farmers who now hire large amounts of casual labor would severely affect the incomes of agricultural laborers, not only because sowing and harvesting are the only times in which casual labor can earn high wages, but also because these are the only months in which most agricultural laborers are practically assured of continuous employment throughout the month. Furthermore, much of this new equipment replaces bullock power as well as human labor, thus further reducing the income of small farmers who hire out their bullocks as well as their labor.

Wider Implications

If the widespread adoption of new technology assumed for the Bisauli block does in fact occur, similar changes will doubtless occur throughout Western Uttar Pradesh. The assumption that product prices are constant is not tenable for areas much larger than a block. To assess the validity of extrapolation of the results, the model was solved using alternative sets of product prices with all prices set lower than or equal to the 1968–69 prices originally used. The results show that crop incomes are reduced substantially by lower product prices; cropping patterns, crop output, wages, and levels of employment are less affected; time patterns of wages and employment and the relative incomes of various rural groups are not greatly affected by lower product prices. Thus, it appears that the implications of new technology for employment and wage patterns and for relative incomes in Western Uttar Pradesh will be much the same as in the Bisauli block.

A more rigorous method of allowing for downward-sloping product demand functions at the regional level would be to incorporate stepped demand functions for products in the form of sets of marketing activities for each product with successively lower selling prices.[12] Such a procedure would increase the complexity of the model but would also increase its usefulness as a policy tool at the regional or state level.

[12] Yaron, Plessner, and Heady [14] describe regional programming models incorporating stepped product demand functions.

Conclusions

The results of this study imply that widespread adoption of new agricultural technology in the Bisauli block will roughly double crop production in the block. The disparity between the incomes of large and small landholders in the block will be reduced if short-term funds and chemical fertilizers are distributed on the basis of productivity or area operated. The total amount of agricultural employment in the block will increase 30 to 50 percent, and average agricultural wages will rise, but the increase in agricultural laborers' incomes due to changes in crop production will be less than the corresponding increase in farmers' incomes. If the possibility of changes in the nonfarm sector and in agricultural production other than crop production is ignored, adoption of new agricultural technology will therefore increase the disparity between the incomes of these two groups. If labor-saving machinery is widely introduced on the larger farms in response to high wages in harvest months, incomes of agricultural laborers will be substantially less than would have otherwise been the case, and the disparity between the incomes of the farmers and the laborers will be increased still more.

Notwithstanding the limitations of the estimates presented in this paper, results concerning future patterns of employment and wages and future relative incomes are felt to be sufficiently definitive to suggest some general prescriptions for agricultural policy. First, it appears desirable for government agencies to proceed cautiously with projects designed either to increase the supply of or to stimulate farmer adoption of machines capable of replacing substantial quantities of human labor. Second, with respect to the relative positions of the larger and smaller landholders, it is desirable on both efficiency and equity grounds that the government ensure that the small farmer will get at least equal access to supplies of short-term funds and fertilizers on the basis of area operated.

References

[1] BILLINGS, MARTIN H., AND ARJAN SINGH, "Mechanization and Rural Employment," *Econ. & Polit. Weekly* 5:A61–A72, June 27, 1970.

[2] JOHL, S. S., AND A. S. KAHLON, *Application of Programming Techniques to Indian Farming Conditions*, Ludhiana, Department of Economics and Sociology, Punjab Agricultural University, 1967.

[3] JOHNSTON, BRUCE F., AND JOHN COWNIE, "The Seed-Fertilizer Revolution and Labor Force Absorption," *Am. Econ. Rev.* 59:582–596, Sept. 1969.

[4] KANEDA, HIROMITSU, "Economic Implications of the 'Green Revolution' and the Strategy of Agricultural Development in West Pakistan," *Pakistan Dev. Rev.* 9:111–143, Summer 1969.

[5] LADEJINSKY, WOLF, "The Green Revolution in the Punjab," *Econ. & Polit. Weekly* 4:A73–A82, June 28, 1969.

[6] MADALGI, S. S., "Foodgrain Self-Sufficiency in Fourth Plan," *Econ. & Polit. Weekly* 4:A71–A72, June 28, 1969.

[7] SINGH, I. J., "The Transformation of Traditional Agriculture: A Case Study of Punjab, India," *Am. J. Agr. Econ.* 53:275–284, May 1971.

[8] SRIVASTAVA, U. K., R. L. CROWN, AND E. O. HEADY, "Green Revolution and Farm Income Distribution," *Econ. & Polit. Weekly* 6:A163–A172, Dec. 25, 1971.

[9] SWANSON, E. R., "Programmed Normative Agricultural Supply Response: Establishing Farm-Regional Links," in *Economic Models and Quantitative Methods for Decisions and Planning in Agriculture*, ed., Earl O. Heady, Ames, Iowa State University Press, 1971, pp. 229–242.

[10] Uttar Pradesh Agricultural University, *Changing Agriculture and Rural Life in a Region of Northern India*, Vols. I and II, Pantnagar, 1969.

[11] Uttar Pradesh, Directorate of Agriculture, *Bulletin of Agricultural Statistics for Uttar Pradesh, 1967–68*, Lucknow, 1969.

[12] WHARTON, CLIFTON R., "The Green Revolution: Cornucopia or Pandora's Box?" *Foreign Affairs* 47: 464–476, April 1969.

[13] WILLS, IAN R., "The Implications of the Green Revolution for Future Production, Income and Employment in Agriculture in Western Uttar Pradesh, India," unpublished Ph.D. thesis, University of Illinois, 1970.

[14] YARON, DAN, Y. PLESSNER, AND E. O. HEADY, "Competitive Equilibrium—Application of Mathematical Programming," *Canadian J. Agr. Econ.* 13:65–79, 1965.

Strategies for the Creation and Transfer of the Farm Estate*

MICHAEL D. BOEHLJE AND LUDWIG M. EISGRUBER

This article develops an estate management model that considers interrelationships between estate creation and transfer, as well as the uncertainty of the parent's(s') death. The estate management problem is conceptualized as an adaptive sequential decision problem and the simulation model used in the empirical analysis is briefly reviewed. Empirical results suggest that high growth rate creation and transfer plans which include substantial lifetime gifts are essential elements of high response estate management strategies. Implications for business organization and coordination of the entry and exit processes of farmers are briefly discussed.

The Problem

THE GROWING capital requirements of viable farm firms, the increasing average age of farmers, and the predominance of sole proprietorship in agriculture have generated recent interest in the problems of transferring property between generations [5, 13, 14, 16, 22, 25]. However, the problems of planning for the transfer of an estate are compounded by the need for simultaneous consideration of strategies used for capital accumulation and growth. Thus, estate *management* planning involves the development of a comprehensive plan to ensure the economic management of the estate property *during and after* the lifetime of the estate owner as well as to create the desired legal consequences in the transfer of the property. This interrelationship between *creation* of an estate (firm growth) and *transfer* of the estate between generations is accepted in concept but has thus far defied empirical analysis. Generally, we are unsure of the variables which provide for this interrelationship and the various strategies that may be used to coordinate the creation and transfer processes.

Previous analyses of intergeneration transfers of farm estates have coped inadequately with the interrelationships between creation and transfer. They also have not considered the uncertainty of death. Typically, the optimum estate plan has been developed for an estate of known size and composition based on the premise that the date of death of the parent(s) is known with certainty [2, 15, 19]. These basic assumptions are certainly severe abstractions from reality.

The following discussion presents an empirical analysis of the estate management problem when (a) the date of death of the parent(s) is known only in a probability sense—and the probabilities change over time—and (b) the firm creation process and the firm transfer process are integral parts of the analysis. The empirical results are discussed for both a case estate and other estate-family situations representative of Corn Belt farms.

The Analytical Model[1]

Family and estate characteristics and legal consequences must be considered in the choice between various estate management alternatives. Tax and distribution consequences of various will and gift arrangements must be evaluated with the available knowledge of the probabilities of the parents' deaths as determined by their ages and health. In addition, when the parent's(s') date of death is known only in a probabilistic sense, future plans for the investment of earnings and the implementation of production decisions must be made. Thus, the estate management problem requires dynamic analysis that includes the dimensions of time and uncertainty. The adaptive sequential decision model encompasses these dimensions [24]. The structure of an adaptive sequential decision problem can be summarized by the following functional relationships:

Decision Function

$$(1) \qquad X_k^* = \alpha(U, I_k)$$

Criterion Function

$$(2) \qquad U = \pi(\hat{Y}); \quad \hat{Y} = [Y_1, Y_2 \cdots Y_k]$$

Information Transition Function

$$(3) \qquad I_k = \sigma(Z_{k-1}, I_{k-1})$$

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MICHAEL D. BOEHLJE *is assistant professor of agricultural economics at Oklahoma State University, and* LUDWIG M. EISGRUBER *is professor of agricultural economics at Purdue University.*

[1] Although this discussion is necessary for a complete understanding of the complexity and interrelationships of the estate management problem and the precision and limitations of the results, the less theoretically oriented reader may desire to go directly to the discussion of the empirical model.

Outcome Function

$$Y_k = \phi(X_k, Z_k, S_k) \tag{4}$$

Structural State Transition Function

$$S_k^{\cdot} = \lambda(X_{k-1}, Z_{k-1}, S_{k-1}) \tag{5}$$

Where

X_k = the course of action or decision vector in period k (if starred (*), is the optimal decision vector);
I_k = the information vector in period k;
U = the level of utility;
$\hat{Y}$ = the outcome vector over all periods ($k=1, 2, \cdots K$);
Y_k = the outcome vector in period k;
Z_k = the environmental state vector in period k;
S_k = the structural state vector in period k.

The decision problem is to choose the optimal set of $X_k^*(k=1, \cdots, K)$ from all feasible X_k according to the decision rules specified by the alpha (α) function, given the pi (π), phi (ϕ), lambda (λ), and sigma (σ) functions. The relationships and variables of the estate management problem will be discussed briefly within this conceptual framework.[2]

The decision function (equation 1) indicates that the optimal decision vector in each period (the annual creation and transfer decisions) is dependent upon both the utility (U) associated with that strategy (the sequence of creation and transfer decisions during the planning horizon) and the data on the environmental states contained in the current information vector (I_k). If these data are uncertain in nature but can be approximated by a subjective probability distribution that changes over time, a Bayes formulation of the alpha (α) function is appropriate [7, 10, 20, 26]. This formulation involves choosing that strategy which maximizes the weighted value of the utility for all environmental states, the weights being defined by the probabilities (of death of the parent(s) in this study) associated with each environmental state.

Utility (equation 2) is measured as the present value of the net estate transferred to the heirs during the planning horizon. This value is calculated for each environmental state from a set of recursive equations as the present value of the gift and will transfers to the heirs minus transfer costs in each period plus the present value of the transferred estate from the subsequent period to the end of the planning horizon. This specification of the pi (π) function is a simple extension of the Fisher criterion of maximization of the purchasing power of a bundle of investments [11, 12]. However, this purchasing power is not measured in terms of withdrawals for direct consumption by the parents, but in terms of withdrawals for transfer to the heirs. Because transfer costs are incurred in the withdrawal process, the total net value of the withdrawals is measured as the discounted value of the estate in the hands of the heirs. The discount rate is assumed to be equal to the borrowing rate of interest. Thus, the major difference between the authors' criterion function and that used in most investment analyses is the inclusion of the event of death and the resulting capital transfers during the planning horizon.

Environmental states in the estate management problem are specified by the mortality of the parents. A mortality is defined as a particular sequence of life and death *events* during the planning horizon. The probability of each mortality is calculated as the compound probability of a specific life or death event *in* each period times the probability of a sequence of life and death events *during* the previous periods. This current probability distribution on mortalities is contained in the information vector (I_k). Thus, the alpha (α) function of equation (1) is specified as the maximization of the weighted average of the present value of the transferred estate, the weights being defined by the mortality probabilities. The decision vectors for all periods ($k=1, \cdots, K$) associated with this maximum value is the Bayes strategy.

In the adaptive formulation data in the current information vector are dependent upon the previous environmental state and the previous information vector as indicated by equation (3). Thus, the probability of each current mortality depends upon what death events have occurred in the previous period and the probabilities associated with these events. If both parents have lived through the previous period, then the probabilities of four death events can be calculated for the current period (husband dies and wife lives, husband lives and wife dies, both live, and both die). If the husband or wife has died previously, the surviving spouse can either live or die in any period.

[2] A more specific mathematical statement of the estate management problem can be found in a dissertation by Boehlje [3].

The probability of each type of death event is also dependent on the parents' ages at the beginning of the planning horizon and the number of periods in the planning horizon that have elapsed. The probability for any life or death event in any period can be obtained from a survival function or a mortality table [17]. Thus, each weight or mortality probability is dependent on the mortality probabilities in the previous period (I_{k-1}) and the environmental state or death event that occurred in the previous period (S_{k-1}).

The phi (ϕ) function of equation (4) is simply an input-output transformation function that assigns a particular vector of outcomes to each combination of courses of action, structural states, and environmental states in period k. In the estate management problem, the will, gift, and ownership decisions, along with the creation decisions, determine the annual outcome as measured by the gross value of the property transferred to the heirs in each period for each type of mortality.[8] However, constraints on these creation and transfer decisions are imposed by the physical production capacity of the firm, the borrowing limits imposed by lending institutions, the limitations imposed by law on various transfer procedures such as the state laws of descent, and the personal constraints specified by the parents such as the consumption function and the security level of assets to remain in the estate during their lifetime. In addition, the net value received by the heirs in each period is influenced by the tax costs, administration fees, and liquidation losses associated with particular transfer methods. The explicit specification of these transformation relationships and constraints results in the phi (ϕ) function of the estate management problem.

The outcome vector in each period is dependent upon the structural state in that period as indicated by equation (4). Equation (5) indicates that this structural state depends on the values during the previous period of the environmental state, the decision, and the structural state vectors. Thus, the structural state transition function (the lambda (λ) function) indicates the results in terms of annual net income, asset composition and net worth of the firm, ownership structure of the firm, amount and type of property received by various heirs, amount and type of property remaining in the estate, and transfer costs of estate management decisions made in previous periods for different mortality situations.

[8] The summation of those discounted outcome values for all periods results in the measure of utility.

The Empirical Model

The adaptive sequential decision model of the estate management problem discussed above was transformed into a simulation model for empirical application.

The decision space

The decision space of the empirical model is comprised of alternative methods of creating and transferring the farm estate. A creation plan consists of the specification of a set of production and investment decisions for each of the years within the planning horizon from among the various alternatives. A transfer plan involves the determination of an ownership policy, a gift policy, and the elements of a will for each living parent for each of the years within the planning horizon.

The creation alternatives.—The production alternatives are defined by various methods of producing corn, hogs, and cattle. Alternative corn production methods include two row widths, seven different tillage-planting technologies, and six different planting time distributions. Thus, the empirical model permits the consideration of 84 alternative ways to produce corn each year. The cattle enterprise includes six different technologies for two alternative weights of cattle, or 12 techniques of production in each year. The hog enterprise can be divided into three sub-enterprises—farrowing and selling of feeder pigs, farrowing and finishing of market hogs, and buying feeder pigs and selling them at market weight. Farrowing and selling feeder pigs can be accomplished with a two- or four-litter system in 13 alternative farrowing, gestation, and nursery facilities during six alternative periods of the year. The farrow-finish operation includes the previously identified hog production alternatives plus four alternative finishing facilities. Feeder pigs can be purchased in two or three lots during the year and fed in four alternative production facilities during eight alternative time periods. Thus, the model contains 456 alternative ways to produce hogs in each year.

Investment alternatives include six different types of cattle facilities, 17 alternative types of hog facilities, and 10 different tractor sizes, six types and up to 10 sizes of land preparation and planting equipment (chisel, harrow, disc, plow,

and planter), and two types and four sizes of harvesting equipment that can be used in corn production. The machinery investment decisions also include the timing of machinery replacement as well as the alternatives of purchasing new or used equipment. Finally, funds can also be used to acquire land with four different types of financial arrangements or to purchase nonfarm assets such as stocks and bonds. All of these investment alternatives are available in each year (subject, of course, to the usual constraints such as liquidity).

The transfer alternatives.—The transfer alternatives that are included in the model for each year are summarized in Figure 1. The alternatives identified in this figure are those available if both parents are alive. Obviously, if only one parent is alive, only one type of ownership is possible, only one will is needed, and the number of gift alternatives available is substantially reduced. Thus, the scope of the creation decisions which can be made in any period is limited by the type of mortality that has occurred in the previous period.

There are two types of wills. A simple will implements state laws of descent and does not name an executor for the will. A complex will enables division of property among the heirs in a different proportion than that specified by the laws of descent. In addition, it is assumed that an executor who handles the probate proceedings for no fee is named in the complex will. If a "straight" will is chosen, the heirs receive unrestricted ownership of the property. In the trust arrangement, the spouse receives her share of the property with no restrictions, but the children's shares are placed in trust with the spouse as co-trustee and the children as beneficiaries. Gifted property in trust is treated in the same manner. A management fee is charged on all property held in trust.

Searching the decision space

A statistical approximation or modified Monte Carlo procedure was utilized to search the decision space for the optimal decision vector [X_k* of equation (1)]. The traditional Monte Carlo procedure utilizes the random sampling process to choose specific values for the decision variables consistent with the constraints imposed on the decision space (integer values, mutually exclusive alternatives, etc.) [1, pp. 350–354; 21]. However, many of the solutions generated by the simple Monte Carlo procedure will not utilize all of the available resources. By combining the Monte Carlo method with a "hill-climbing" procedure, solutions can be generated on the boundary or the constraint set of the decision space [9, 28, 29]. Thus, interior solutions which are not bounded by any constraint are eliminated.[4]

Results

The case estate

To obtain realistic data to use in testing the empirical model and to ensure a critical evaluation of the results, a specific case estate was analyzed. The case estate is owned by a 74-year-old widow in central Indiana who has two children, a married son who is operating the farm with a share-lease arrangement and a married daughter. The size and composition of the estate and firm assets are summarized in Table 1.

The best strategy.—The best estate management strategy (i.e., the best set of creation and transfer decisions for all contingencies over the entire planning horizon) ascertained for the

[4] While the model used in this study contains its own unique search algorithm, the interested reader is referred to work by S. C. Thompson [30] for a complete description of an algorithm which is very similar to the one used in this study.

Table 1. Size and composition of the estate of a 74-year-old widow (1970)

Item	Value Owned by Widow
Real Estate & Improvements	
Farm Real Estate	$202,400
Sow Maintenance Facility	$ 1,200
Sow Farrowing Facility	$ 15,660
Pig Nursery Facility	$ 1,860
Pig Finishing Facility	$ 14,208
Cattle Finishing Facility	$ 17,000
Urban Real Estate	$ 27,000
Farm Personal Property	
Row-Crop Tillage & Planting Equipment	—
Power Equipment	—
Harvesting Equipment	—
Crop & Livestock Inventory	$ 21,454
Cash	$ 22,550
Outside Investments	
Checking & Savings Account	$ 30,200
Certificates of Deposit	$ 8,500
Stocks & Bonds	$ 18,000
Home Furnishing & Auto	$ 4,300
Insurance	
Whole Life Policy	$ 1,000
Total Value[a]	$385,332

[a] In addition, the children owned land (140 acres) and equipment valued at $79,956. These assets were inputs to the total farming operation. The children also participated in the farm operation with livestock and supplies equivalent in value to that of their parents.

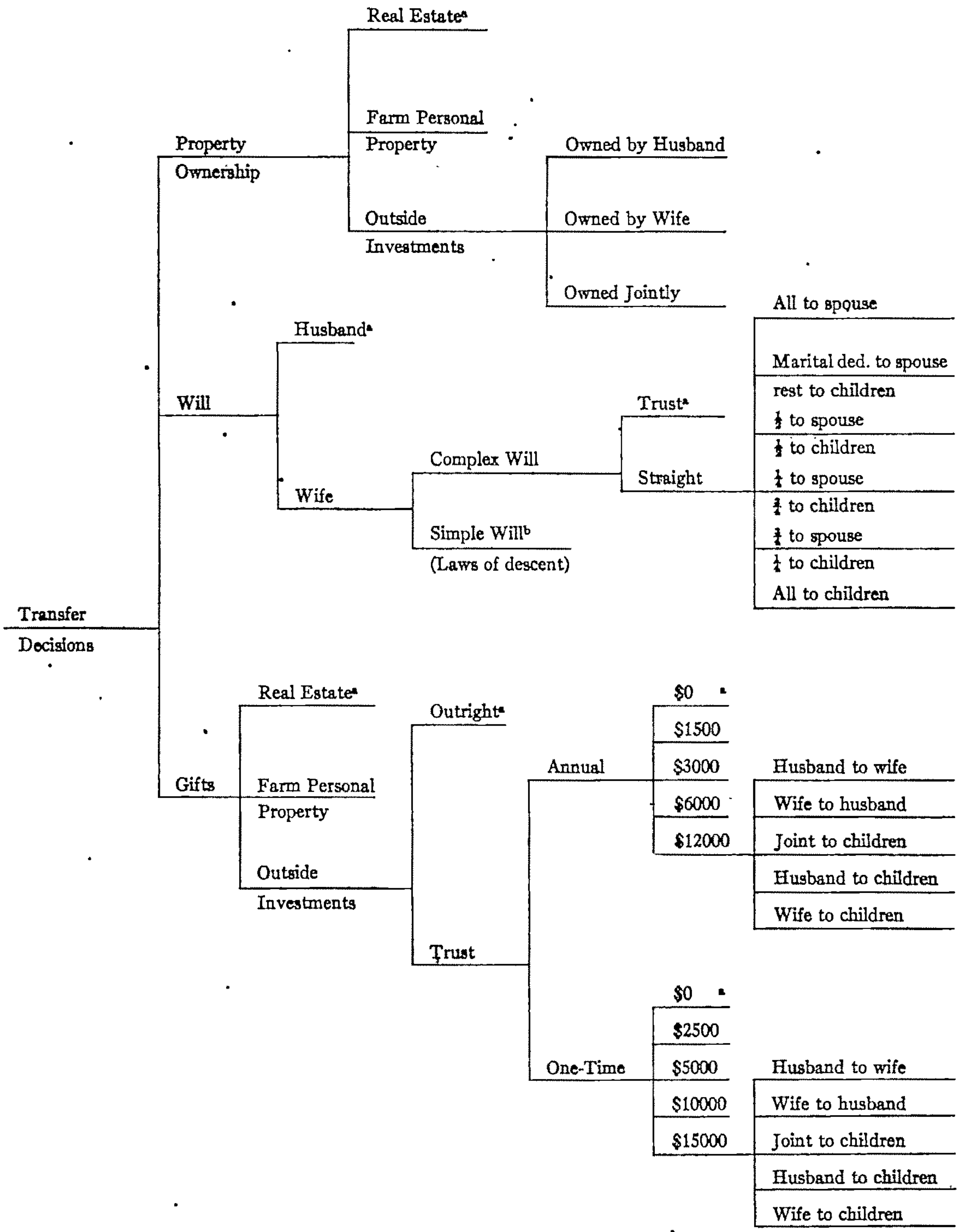

Figure 1. The Transfer Decision Alternatives

[a] These branches have been terminated in this figure because of space limitations. The alternatives available in the model if these branches are chosen are identical or similar to those indicated on the intra-connected branch that is continued in this figure.

[b] The simple will specifies that outright ownership in the proportion of the property specified by the laws of descent is given to the heirs. Thus, this branch is terminated.

case estate is summarized in Table 2. Annual creation plans include the corn, cattle, and hog enterprises which are expanded from the first through the sixth year of the planning horizon. However, an enterprise reorganization in the seventh year results in a decrease in the size of these enterprises.[5] The net worth of the firm increases from $470,826 at the end of the first year to $631,130 at the end of the tenth year; by the last year of the planning horizon the firm controls $684,211 of assets.

Transfer plans that include substantial amounts of gifts are part of the best estate management strategy for the case estate. A total of $124,000 of property is transferred by gift from the widow to the heirs during the planning horizon, resulting in a total gift tax liability of $8,366. The widow uses a complex will during the first six years of the planning horizon, but in year seven changes to the simple will. If the widow were to die in the first year, $379,072 of property would be transferred to the heirs under the will. Approximately $109,000 in costs would be incurred in this transfer, including $80,955 of estate tax, $9,770 of state inheritance tax, and $18,068 of administration and closing costs. In the tenth year, a total of $463,444 of property with a present value of $260,492 is transferred to the heirs if death occurs. Total cost of implementing the transfer decisions has risen to $178,061 by the end of the planning horizon.

Stability of the best strategy.—A comparative analysis of the strategies investigated for the case estate suggests that high growth rate creation plans are associated with large values of the transferred estate. These high growth rates in firm and estate size are generated by diversifying into the crop, livestock, and outside investment enterprises rather than concentrating in any one of these enterprises. Transfer plans that include a large amount of gifts also are associated with high value estate management strategies, but no specific type of will appears to be associated with high values of the transferred estate. Total transfer costs in excess of $100,000 are incurred in all of the high value strategies for the case estate, irrespective of when the widow dies.[6]

Impact of early death.—There is always a possibility that the parent or parents may die prior to the end of the planning horizon and before all of the estate management plans implied by the best strategy can be implemented. Thus, it is important to evaluate various estate management strategies with respect to their performance when early death occurs. Present value of the transferred estate at the end of a given year, assuming death has occurred in that year, is used to evaluate the performance of various strategies.

Present value of the transferred estate at the end of each year consistently decreases from about $260,000 in the first year to $140,000–$170,000 in the last year for the low response strategies (Fig. 2). This decline is mainly attributable to the low or negative growth rates of these low response strategies. In contrast, the present value of the amount of property the heirs would receive in a given year if the widow died in that year is much greater for the high response strategies, particularly in the later years of the planning horizon. Thus, the high

[5] This unexpected result is explained by the fact that some of the existing cattle facilities had deteriorated to the point where they had to be replaced by year seven. Rather than replacing all of these facilities, it appeared more profitable to replace only some of these facilities and to shift to the more labor-intensive calf-feeding operation. This higher demand on labor also necessitated a decrease in the size of the corn enterprise as well as a change in corn production technology.

[6] Not all possible transfer possibilities are explored in this study. Notably absent are the life estate arrangements and the possibility of incorporation with its unique transfer implications. Therefore, these conclusions have to be accepted with a caveat.

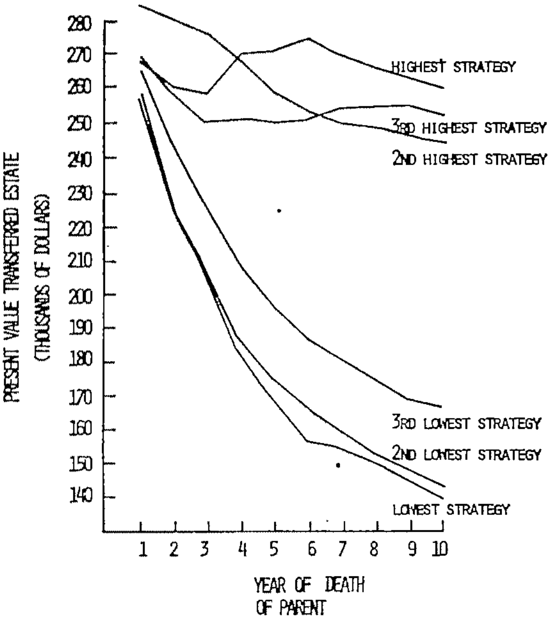

Figure 2. Annual Present Values of the Transferred Estate (Single Parent Case)

Table 2. Annual estate management plans for a 75-year-old widow with two children and a $385,000 initial estate

Management Plans	Years 1	2	3	4	5	6	7	8	9	10
Creation Plans										
Corn	520(FPDHP)[a]	600(FPDHP)	760(FPDHP)	800(SPDHP)[a]	800(SPDHP)	800(SPDHP)	560(SPCUP)[a]	560(SPCUP)	560(SPCUP)	560(SPCUP)
Hogs	—	—	—	—	—	—	—	—	—	—
Cattle	650(Y)[b]	750(Y)	950(Y)	1000(Y)	1000(Y)	1000(Y)	350(C)[b]	350(C)	350(C)	350(C)
Outside Investments[c]	$ 13,000	$ 15,000	$ 19,000	$ 20,000	$ 20,000	$ 20,000	$ 14,000	$ 14,000	$ 14,000	$ 14,000
Ending Net Worth[d]	$470,826	$458,769	$463,177	$482,436	$506,995	$530,456	$556,797	$577,783	$604,599	$631,130
Ending Total Assets[e]	$493,083	$492,978	$571,219	$614,532	$607,872	$640,533	$666,562	$679,351	$678,631	$684,211
Percent Return[f]	+1.19	+1.46	+4.61	+4.51	+5.12	+4.65	+4.99	+3.97	+4.86	+4.62
Value Widow's Property[g]	$397,072	$395,162	$399,892	$425,902	$445,058	$473,857	$497,860	$507,333	$519,498	$530,505
Value Children's Property[g]	$ 73,749	$ 63,602	$ 63,268	$ 56,517	$ 61,918	$ 56,581	$ 58,916	$ 70,433	$ 85,079	$100,603
Transfer Plans Gift Policy										
Widow to Children[h]	$ 18,000	$ 18,000	$ 18,000	$ 6,000	$ 6,000	$ 6,000	$ 13,000	$ 13,000	$ 13,000	$ 13,000
Widow's Gift Tax	$ 540	$ 1,080	$ 1,440	—	—	—	$ 1,035	$ 1,555	$ 1,313	$ 1,403
Will Policy (implemented if the widow would die in each year)										
Type of Will[i]	Complex[i]	Complex	Complex	Complex	Complex	Complex	Simple[i]	Simple	Simple	Simple
Amount to Children[j]	$379,072	$377,162	$381,892	$419,902	$439,058	$467,857	$484,860	$494,333	$506,498	$517,505
Federal Estate Tax	$ 80,955	$ 84,270	$ 89,038	$ 96,682	$ 99,717	$105,745	$108,328	$111,578	$115,732	$118,246
Indiana Inheritance Tax	$ 9,770	$ 10,231	$ 10,342	$ 11,317	$ 11,590	$ 12,712	$ 13,218	$ 13,834	$ 14,271	$ 14,682
Administration Costs[k]	$ 18,068	$ 18,792	$ 19,815	$ 20,986	$ 21,308	$ 22,064	$ 33,416	$ 34,487	$ 35,732	$ 36,448
Total Transfer Costs[l]	$109,434	$115,113	$122,555	$132,444	$136,174	$144,180	$159,687	$165,808	$172,988	$178,061
Current Value Transferred Estate[m]	$287,639	$298,049	$313,337	$347,458	$368,884	$395,677	$410,173	$426,525	$444,510	$463,444
Present Value Transferred Estate[n]	$268,821	$261,389	$258,790	$270,791	$271,550	$275,109	$269,867	$265,944	$262,993	$260,492

[a] FPDHP indicates the use of a fall plow, spring disc, harrow, and plant production system. SPDHP denotes a spring plow, disc, harrow, and plant production system. SPCUP denotes a spring plow, field cultivate, and plant production system.
[b] Y denotes the purchase and feeding of yearling cattle (700 pounds). C denotes the purchase and feeding of calves (450 pounds).
[c] The amount of funds invested in nonfarm assets this year.
[d] Net worth of the firm at the end of the year.
[e] Value of the total assets controlled by the firm at the end of the year.
[f] Percent return on owned capital *after* consumption and income taxes.
[g] Value of the property included in the firm that is owned by the widow and by the children.
[h] Indicates the amount of property transferred from the widow to the children as gifts.
[i] *Simple* indicates a simple will that implements the state laws of descent and does not name an executor for the will. *Complex* indicates a complex will which enables the division of property among the heirs in a different proportion than that specified by the laws of descent. It is also assumed that an executor with no fee is named with a complex will, thus eliminating the executor fee and reducing the administration and closing costs.
[j] The amount of property transferred by the will from the widow to the children.
[k] The administration, legal, and court costs incurred in administering or executing the will and closing the estate.
[l] Includes all direct costs (death taxes, gift taxes, estate planning, and management fees) of implementing the gift decisions through the specified year and the will decisions if death would occur in the specified year.
[m] Calculated as the non-discounted sum of previous annual gifts plus the amount transferred by will if death would occur on the specified year less all transfer costs.
[n] The net value of all transfers if death would occur in the specified year (accumulated gift plus will transfers less transfer costs) discounted at 7 percent to the beginning of the planning horizon.

response strategies, which typically include large amounts of annual gifts, appear to have the best performance regardless of whether death of the parent(s) occurs early or late in the planning horizon.

Impact of selected factors on estate management

One might expect that the best estate management strategy is significantly influenced by certain estate-family characteristics. Thus, the above results and conclusions may be valid only for the particular characteristics of the case estate. To examine this hypothesis and to obtain a higher degree of generality from the results of this study, the impacts of the initial size of the estate, the age of the parents, and the number of parents alive on the best creation-transfer strategy were investigated. Table 3 summarizes the factor levels that were investigated for each of the three factors. Results of this investigation are presented below, first for the case where only one parent is alive and then for the two-parent situation.

Single-parent estate strategies.—*Estate management and age.* The results of factor levels (1) and (2) of Table 3 were compared to determine the impact of age on the best single-parent estate management strategy. Surprisingly, the best strategies were identical for the 74-year-old and the 44-year-old widow. Similarity in management strategies for the two different ages can be explained by two related arguments. First, the annual creation plans appear to have as much or more influence on the value of the transferred estate than the transfer plans when only one parent is alive. The best strategy for the older widow includes a set of creation plans that results in a substantial increase in the estate size after 10 years and a large amount of property transferred to the heirs. If the creation plans dominate the transfer plans and are independent of age, high value estate management strategies may be very similar for single estate owners of quite different ages.

Table 3. Factors and their levels investigated with the empirical model[a]

Description of Factor	Factor Levels (1)	(2)	(3)	(4)	(5)
Size of Estate (Approx.)[b]	\$400,000	\$400,000	\$600,000	\$150,000	\$400,000
Age of Parents (husband/wife)	79/74	49/44	79/74	79/74	64/59
Number of Parents Alive[c]	1	1	1	1	2

[a] This is only a fractional design (cf. [8], pp. 244–276).
[b] The 400,000 estate refers to the case estate. The asset composition of the two other estate sizes was proportional to the case estate.
[c] If only one parent is alive, it is assumed to be the wife.

The second and related explanation is provided by the structure of the empirical model. When one or both of the parents are still alive at the end of the planning horizon, it is necessary to add to the response function the *transferable value* (value of all property net of transfer costs) of the property they still own. The probability of living for at least another 10 years is .93 for a 44-year-old widow compared to .38 for a 74-year-old widow. Consequently, in computing the weighted value of the transferred estate, the *transferable* estate is weighted more heavily for the younger widow compared to the older widow. Thus, strategies that include high rates of growth in estate size are even more important for the young widow who has a high probability of living beyond the planning horizon.

It should be noted that the estate transfer plans for the young widow *did* include substantial gifts, even taxable gifts. However, the gifted property is mainly outside investments which are not part of the firm and farm personal property. Personal property remains in the firm and thus does not significantly impair the growth rate of the firm and estate. Consequently, reallocating *ownership* structure of the firm to the children resulted in a larger transferred estate even for the young widow.

Estate management and estate size. Factor levels (1), (3), and (4) of Table 3 were compared to determine the impact of estate size on the best strategy. Annual creation plans that generate high net returns and large rates of firm and estate growth are part of the highest value strategy for all three estate sizes. Low values of the response function are associated with low rates of growth in firm and estate size. To obtain a high rate of growth in estate size, it appears that the creation plans should include substantial outside investments. The best strategies for the large, medium, and small estates include a 10-year total of \$173,000, \$163,000, and \$225,000 of new outside investments, respectively. Because labor is the most limiting resource for all three estate sizes, production technologies that are labor saving are also included in the creation plans. Thus, regardless of estate size, an estate management strategy which includes outside investments and high growth rate creation plans usually generates the largest amount of property transferred to the heirs.

The best transfer plans for all three estate sizes indicate that substantial gifts, even taxable gifts, should be given to the heirs regardless of estate size. Even in the case of the small estate, almost $90,000 of property is transferred as gifts from the widow to the children during the planning horizon in the best strategy. Although a complex will results in lower transfer costs at death than a simple will, the impact of the will decision appears to be dominated by other creation-transfer decisions when the probability of death is considered and only one parent is alive.

Relationship between the annual estate tax liability, the total transfer cost, and the *current* value of the transferred estate if the widow would die in any year is summarized in Figure 3 for the three estate sizes. The significant increase in total transfer costs from the sixth to the seventh year for the two large estates clearly indicates the additional cost incurred when a change is made from a complex to a simple will. Figure 3 also indicates that the value of the transferred estate increases more rapidly over time than do the costs of transfer. Thus, even though the federal and state estate tax rates are very progressive, a well-developed, dynamic estate management strategy can offset this progressive structure and result in the transfer of a *larger* proportion of an increasingly *larger* estate to the heirs.[7]

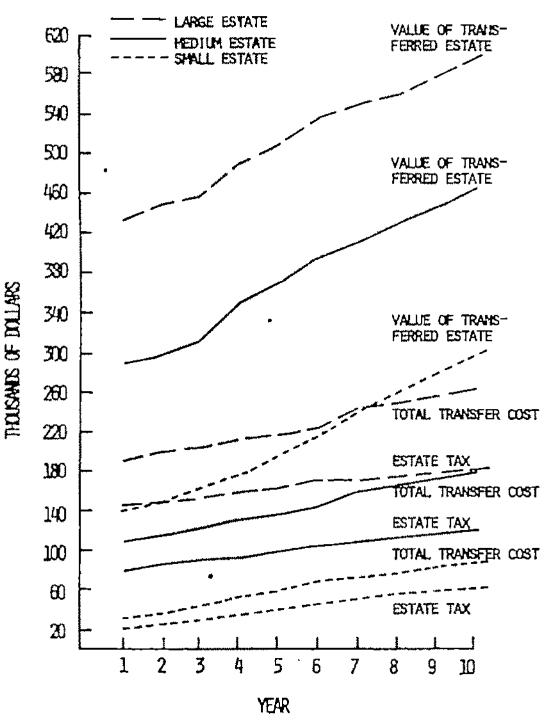

Figure 3. Estate Tax, Total Transfer Costs and Current Value of the Transferred Estate for the Three Estate Sizes (Single Parent Case)

Finally, the *difference* between the annual present values of the transferred estate generated by the highest value compared to the lowest value strategy is almost equal for the three estate sizes. By the tenth year the best strategy has transferred almost $100,000 (present value) more property to the children than the lowest value strategy for each estate size. Thus, the transferred value compared to estate size is much higher for the small estate, and contrary to popular belief, a well-developed management strategy may be relatively more valuable for the small estate than for the large estate.

Two-parent estate strategies.—Determination of the best estate management strategy is much more complex when two parents are alive than when only one parent is living. The ownership decision is not predetermined in the two-parent situation (new assets can be owned by the husband, by the wife, or jointly) and property can be transferred by gift from both parents to the children as well as between the parents. Not only must the provisions of two wills be determined when both parents are alive, but there are also more alternative types of wills that must be analyzed. In addition, more types of mortality can occur in the two-parent case. Because of this increased complexity, a six-year planning horizon is used instead of the 10-year horizon used for the one-parent case. The following discussion summarizes the best estate management strategy for two parents in their early sixties who have two children and a $400,000 estate.

The annual creation plans generated for the best two-parent strategy include the corn, hog, and outside investment enterprises. Corn production expands from 640 acres in the first year to 960 acres in the sixth year if both parents are still living. During this same time hog production increases from 1,292 head of market hogs to 2,031 head of feeder pigs and annual purchases of off-farm assets increase from $20,000 to $30,000. However, if either parent dies before the fourth year, transfer costs are high enough that some productive assets must be liquidated. In this situation, firm expansion is limited and the size of the enterprises in the sixth year is

[7] It should be noted, however, that the ratio of transfer costs to value transferred increases with estate size.

only slightly larger than the enterprise size in the first year.

Although the annual net return is only 3.5 percent for the first and second years, annual returns of 5 to 6 percent are generated by the creation plans for almost all mortality combinations after the second year. By the end of the sixth year, a firm net worth between $537,293 and $574,177 has been generated, depending upon the mortality. About $160,000 of intermediate and long-term capital is borrowed by the firm during year six for each mortality.

The ownership structure of the firm obviously changes when one or both of the parents die, but the results for the best strategy indicate that ownership structure changes significantly even when both parents live to the end of the planning horizon. At the end of the first year, $69,991 of the firm's net worth is owned by the children, $144,745 is owned outright by the wife, and $267,334 is owned jointly by the husband and the wife. In the sixth year the ownership structure has changed so that the children now own $216,776 of the firm's net worth, the wife owns $90,314, the husband owns $113,615, and $153,292 is owned jointly by the husband and wife. Thus, the amount of property owned jointly is reduced over time and the outright or sole ownership of property by the husband or wife is adjusted so that they both own approximately equal amounts.

The gift policy accounts for the large percentage of the firm owned by the children in the sixth year when both parents are still alive. The parents give a total of $195,000 of property to the children as gifts during the planning horizon, resulting in a total gift tax liability of $3,162 for the husband and $8,490 for the wife.[8] Even after the death of either the husband or wife, substantial amounts of property are transferred as gifts from the surviving spouse to the children. Thus, after the wife dies in the second year, the husband gives a total of $52,000 of property to the children during the following four years.

As in the case where only one parent is alive, a particular type of will is not predominant in the best estate management strategy for the two-parent case. However, a comparison of the best strategies for the single compared to the two-parent situation indicates that a larger proportion of a given size estate can be transferred to the heirs if the management strategy is implemented before the death of one parent.[9]

Conclusions and Implications

The numerical results of this study indicate that the estate management problem requires dynamic analysis of the interactions between the processes of creation and transfer. The highest response estate management strategies ascertained by this study invariably include annual *creation* plans that generate high rates of growth in estate and firm size. Erroneous recommendations will result unless death is recognized as an uncertain rather than a certain event. If death does not occur at the appointed time, investment and production decisions must be made which will change the size and composition of the estate. Thus, a continuing review of the creation-transfer plans by accountants and management specialists as well as lawyers is necessary to ensure proper management of the estate during the parents' lifetime as well as after their deaths.

High growth rate creation plans are an essential part of high response strategies for all three estate sizes investigated. However, high growth rates can be generated by many different enterprise combinations, depending on the technology used in each enterprise. Since labor is the most limiting resource in those situations investigated, high growth rates are associated with labor-saving techniques of production. In fact, choosing the proper technology for each enterprise appears to be as important as choosing the right combination of enterprises.

The outside investment enterprise is included consistently in the best estate management strategies ascertained in this study. Not only does this enterprise generate a 6 percent return without requiring any labor, it also facilitates implementation of transfer plans by providing liquid funds to compensate a nonfarm heir or pay death taxes and administration and closing costs. Although not explicitly explored in this study, it is evident that availability of liquid funds from outside investments can reduce the costs of asset liquidation and asset splitting and, in some cases, eliminate conflicts of interest that might arise because of co-ownership of property [4, 22].

Although the annual transfer plans appear to be dominated by the creation plans, certain

[8] However, some of this tax liability must be attributed to gifts between the parents rather than from the parents to the children.

[9] To some extent this is related to the ability to give more gifts to the heirs tax free and at low tax rates when both parents are alive than when only one is living.

transfer decisions are influential in transferring the largest amount of property to the heirs. Significant amounts of *taxable* gifts are given to the heirs for those combinations evaluated regardless of the age of the parents, the size of the estate, or the number of parents living. Thus, the traditional estate planning rule of thumb that gifts should not exceed the annual exclusion or lifetime exemption is not supported by this study.[10] The numerical results also indicate that almost all of the property transferred by gift is real estate or farm personal property that remains intact in the firm.[11] If property transferred to the children remains intact in the firm, the firm can continue to exploit economies of size and capital-intensive technologies which contribute to high rates of growth. Thus, there may be significant advantages to business organizations such as the closed corporation which can accommodate reallocation of property ownership in the firm without reducing or changing the size or asset composition of the firm. This business structure might also encourage the transfer of managerial and financial responsibility of a "going concern" from the parents to the heirs. Transferring these responsibilities during the productive years of the heirs' lives rather than at the death of the parents may possibly provide the incentive required for the heirs to maintain an active interest in management and operation of the farm.

Results of this study suggest that there is little economic justification for choosing among various types of wills. However, the life estate arrangement was not included in this analysis. Recent research indicates that use of a life estate may result in significant savings in death taxes. [6, 23]. In general, the will decision should not be based solely on economic considerations but also on the sociological and psychological characteristics of the family with the objective of reducing conflicts among family members and guaranteeing equitable (not necessarily equal) distribution of the property.

The old cliche that there are two inevitable events in life, death and taxes, is particularly apropos to the estate planning problem when both these events occur simultaneously. The tax and transfer costs amount to almost $200,000 for an estate valued at approximately $600,000, and the transfer costs can be significant even for a small estate. In fact, the economic benefits of proper estate management relative to estate size are most important for the small estate ($150,000) compared to the large estate ($600,000). Regardless of initial estate size, with appropriate planning the relative proportion of the estate that can be transferred to the heirs will increase as estate size increases over time.

During the stage in the life cycle when most farm estate transfers take place, the processes of disinvestment (exit) and establishment (entry) are occurring simultaneously. Parents are usually attempting to relieve themselves of the managerial and financial burdens of operating the farm business. At the same time, an operating heir may be aspiring to establish a resource base and entrepreneurial competence in the agricultural industry. If the two processes of entry and exit are not well coordinated, personal conflicts can arise and significant social costs incurred. Currently, little is known about the processes and the problems of either disinvesting from or getting established in farming, let alone how to coordinate these processes. Other research needs to relate to the process of intergenerational transfer include the retirement requirements of farmers, the magnitude of the equity capital outflow from agriculture through transfer to nonfarm heirs, and the impact of proposed changes in the tax and transfer laws on farm firms and the structure of the agricultural industry.

The analytical model and solution algorithm used in this study of a complex decision situation were found to be highly satisfactory. They can, with relative ease, be adapted to study some of the questions raised in the previous paragraphs. Changes in parameters in order to address other empirical situations are a matter of clerical efforts, although conceptualization of the changes requires careful consideration of various legal, institutional, personal, and other factors. Addition of enterprises and/or consideration of other ownership structures (e.g., partnerships) require the input of a competent programmer analyst, but such additions are judged as relatively straightforward extensions of the model. Finally, it is the authors' opinion that the model used in this study, with reason-

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[10] This conclusion is also supported by the results of Allwood's study [2].

[11] It should be recognized that problems may arise in transferring indivisible assets such as real estate by annual gifts. However, a mortgage or installment land contract that requires annual payments equal to the desired amount of annual gifts can be used to facilitate the transfer of real estate. If the annual payments are forgiven, a gift results. Undivided fractional interests in real estate can also be gifted to the heirs.

able resource inputs, can be developed to be effective in classroom teaching, adult education, and professional counseling. To obtain the ease of input, readable output, and flexibility needed for these purposes, the size of the model and solution time could become a problem. However, these problems were addressed in concurrent studies [18, 27], and indications are that these problems can be surmounted.

References

[1] ACKOFF, RUSSELL L., *Scientific Method: Optimizing Applied Research Decisions*, New York, John Wiley & Sons, Inc., 1962.

[2] ALLWOOD, JAMES K., "A Linear Programming Model for Minimizing the Costs of Intergeneration Transfer of Property," unpublished M.S. thesis, University of Missouri, 1969.

[3] BOEHLJE, M. D., "Strategies for the Creation and Transfer of the Farm Firm Estate," unpublished Ph.D. thesis, Purdue University, 1971.

[4] ———, AND L. M. EISGRUBER, *Estate Management for Indiana Farm Families*, Purdue Ext. Circ. No. 406, 1972.

[5] BOSTWICK, D., *Farm Financial Management Research —A Theoretical Analysis*, USDA, ERS, ERS-389, Nov. 1968.

[6] BUSS, M., "The Economics of Tax Management of the Types of Farm Organizations for Oklahoma Commercial Farms," unpublished Ph.D. thesis, Oklahoma State University, 1971.

[7] CHERNOFF, HERMAN, AND LINCOLN E. MOSES, *Elementary Decision Theory*, New York, John Wiley & Sons, Inc., 1959.

[8] COCHRAN, WILLIAM G., AND GERTRUDE M. COX, *Experimental Designs*, 2nd ed., New York, John Wiley & Sons, Inc., 1957.

[9] DENT, J. B., AND S. C. THOMPSON, "The Application of Monte Carlo Techniques to Feed Mix Problems," *The Farm Economist*, Vol. XI, No. 6, 1968.

[10] EIDMAN, VERNON R., GERALD W. DEAN, AND HAROLD O. CARTER, "An Application of Statistical Decision Theory to Commercial Turkey Production," *J. Farm Econ.* 49:852–868, Nov. 1967.

[11] FISHER, IRVING, *The Rate of Interest. Its Nature, Determination and Relation to Economic Phenomena*, New York, The Macmillan Co., 1907.

[12] ———, *The Theory of Interest. As Determined by Impatience To Spend Income and Opportunity To Invest It*, New York, The Macmillan Co., 1930.

[13] HARL, N., *Estate and Business Planning for the Farmer as a Sole Proprietor*, Iowa State University, Cooperative Extension Service, Law-Econ. 31, Oct. 1967.

[14] HARRIS, M., "Intergeneration Transfer of Farm Wealth," in *Emerging and Projected Trends Likely to Influence the Structure of Midwest Agriculture, 1970–1985*, ed., John Brake, Monograph No. 11, Agricultural Law Center, College of Law, University of Iowa, June 1970.

[15] HARRISON, G., "A Planning Model for the Elderly Farm Estate Holder in Illinois," unpublished M.S. thesis, University of Illinois, 1966.

[16] HEPP, R., "Computerized Analysis of Insurance and Estate Planning Problems," Paper presented at the Ration Formulation and EDP Decision Seminar, Oklahoma State University, Stillwater, May 20, 1969.

[17] JORDAN, CHESTER WALLACE, *Life Contingencies*, Chicago, Society of Actuaries, 1952.

[18] LEE, C. E., "Exploitation of Information for Capital Accumulation Under Uncertainty," unpublished Ph.D. thesis, Purdue University, 1971.

[19] LEVI, DONALD R., AND JAMES K. ALLWOOD, "Legal-Economic Models as a Tool for Optimizing Integeneration Property Transfers," *Am. J. Agr. Econ.* 51:1393–1398, Dec. 1969.

[20] LUCE, R. DUNCAN, AND HOWARD RAIFFA, *Games and Decisions*, New York, John Wiley & Sons, Inc., 1957.

[21] MCMILLAN, CLAUDE, AND RICHARD F. GONZALEZ, *Systems Analysis: A Computer Approach to Decision Models*, Homewood, Ill., Richard D. Irwin, 1965.

[22] MAYNARD, CECIL D., D. B. JEFFREY, AND GLENN LAUGHLIN, *Estate Planning*, Oklahoma State Ext. Serv. Circ. E-726, 1968.

[23] MAYNARD, C., AND M. BOEHLJE, "Reducing Farm Estate Settlement Costs," Oklahoma State University, Agricultural Extension Service, Fact Sheet No. 710, Dec. 1971.

[24] MURPHY, ROY E., JR., *Adaptive Processes in Economic Systems (Mathematics in Science and Engineering*, Vol. 20), New York, Academic Press, 1965.

[25] O'BYRNE, J. C., J. F. TIMMONS, AND N. W. HINES, *Planning Farm Property Transfers Within Families in Iowa*, Iowa Agr. Exp. Sta. Bull. P-125 (rev:), Feb. 1966.

[26] RAE, ALLAN N., "Stochastic Programming, Utility, and Sequential Decision Problems in Farm Management," *Am. J. Agr. Econ.* 53:448–460, Aug. 1971.

[27] SONNTAG, B. H., "Simulated Near-Optimal Growth Paths for Hog Corn Farms Under Alternative Resource, Price and Efficiency Situations," unpublished Ph.D. thesis, Purdue University, Jan. 1971.

[28] STRYG, P. E., "Application of the Monte Carlo Method and Linear Programming in Farm Planning," *Year Book*, Copenhagen Royal Veterinary and Agricultural College, Feb. 1967.

[29] THOMPSON, S. C., "An Approach to Monte Carlo Programming," Study No. 3, Department of Agricultural Economics, University of Reading, Nov. 1967.

[30] ———, "A User's Manual for Monte Carlo Programming," Study No. 9, Department of Agricultural Economics, University of Reading, Sept. 1970.

Short Articles and Notes

EDITOR'S NOTE: The following two papers on minimum wages and the farm labor market by Gardner and Lianos were produced and submitted independently. Although there is some obvious overlap in content, the AJAE editors decided to publish both papers as a set.

Minimum Wages and the Farm Labor Market*

Bruce Gardner

Effects of U. S. minimum wage legislation on farm wage rates and employment are investigated by a reduced-form supply-demand model of the hired farm labor market. Results indicate the extension of minimum wages to some farm labor has significantly increased farm wages and reduced employment, as the marginal productivity theory of factor demand would predict.

Elementary supply and demand analysis applied to labor markets predicts that minimum wage laws which increase wage rates in the markets covered will reduce employment in these markets, but increase employment and reduce wages in non-covered markets. This view, however, has not been universally accepted, even by economists; and empirical evidence on the issue has been scarce. This note is to offer some evidence from the recent history of employment and wages in the farm labor market.

The farm labor market is interesting because it recently changed in status from non-covered to covered. There are three relevant historical periods: (1) before 1938, no federal minimum wage legislation; (2) 1938–1967, minimum wage in some non-agricultural industries (with coverage broadened in 1961); (3) February 1967 and thereafter, extension to some[1] hired farm labor. The non-agricultural minima are predicted to shift the supply curve of farm labor to the right, reducing the farm wage rate below what it would otherwise have been. The extension to farm workers is predicted to create an excess supply of farm labor at the legislated minimum, reducing employment as employers move up their labor demand curves.

* I am indebted to R. M. Fearn, W. D. Toussaint, T. D. Wallace, and the *AJAE* reviewers for helpful comments.

[1] The major exclusion is the non-coverage of workers on farms employing less than 500 man-days of labor in the peak calendar quarter.

Bruce Gardner *is assistant professor of economics at North Carolina State University.*

Estimation of Minimum Wage Effects

In order to identify minimum wage effects unambiguously, it is necessary to hold constant other shifters of the demand for and supply of farm labor. Ideally these would include the opportunity wage of farm labor on the supply side and the product demand curve and the supply curves of other factors on the demand side. In practice, of course, all these functions are not dealt with simultaneously (which requires a multi-market model) but rather some prices are taken as exogenous.

Non-labor inputs

Rather than attempt to estimate the supply function of non-labor inputs, the present model treats their prices as independent variables, following Schuh [2], though this procedure is strictly legitimate only for factors perfectly elastic in supply. Two such prices are used: an index of prices paid by farmers for material inputs (PK) and the price of land (PL).[2]

The opportunity wage

This wage rate should reflect the options actually open to farm workers. A very broad index of non-agricultural wage rates would be an inappropriate measure of the opportunity wage because the schooling, work experience, and other characteristics of farm workers limit their options considerably. On the other hand, no narrow occupational wage would be appropriate either, since various options are open and the available alternatives change over time. As a

[2] The symbols refer to the regressions below. Data sources are given in footnote 6.

compromise, the wage of production workers in manufacturing (WA) was used as an indicator of what farm workers may expect to earn in non-farm employment. To adjust, albeit crudely, for the probability of not obtaining work at all, this wage rate is multiplied by one minus the rate of unemployment.[3]

Product market effects

With respect to product demand, holding product price constant is inappropriate since it is the market equilibrium, not that for an individual firm, which is of interest. Ideally only the exogenous shifters of product demand should be held constant—income, population, tastes.

Lagged adjustment

The model as outlined so far assumes that the labor market is completely adjusted within the time span of observations of the data (one year). There are, however, good reasons for doubting that this occurs. For example, a change in the current year's nonfarm wage rate may not represent the expected normal wage relevant to labor suppliers' decisions. Moreover, the product demand conditions in many crops do not make their effects felt until the year is essentially over. Insofar as decisions by farm labor suppliers and demanders take the form of commitments made on the basis of past information, the model has to be modified.

On the supply side, the *expected* wage, presumably a function of past nonfarm wages, is used as opportunity wage. On the demand side, the expected product price, presumably a function of past product prices, is used. Note that whereas it was stated above that product price is endogenous, past prices are predetermined and hence legitimate independent variables.

The natural way of incorporating these considerations is by means of distributed lags. However, one hestitates to enter the econometric thickets encountered in using the lagged dependent variable as an independent variable. On the other hand, if expectations are formed on the basis of, say, five years experience, it would cost a lot in degrees of freedom to introduce five lagged values of both WA and product price (PX). As a compromise, the Almon type of procedure was used, putting the distributed lag in polynomial form [1]. For both WA and PX a linear form is estimated on five years past data.

To sum up, the independent variables to be used are: a weighted average of past values of WA as the opportunity wage; an index of prices received by farmers (PX), also an average of past values; and PL and PK as shifters of the demand for labor. An additional such shifter is technical change for which there exists no reliable exogenous measure. However, technical change (as well as other left-out variables, perhaps) is probably highly correlated with the included independent variables, even the minimum wage variable, since they all have strong trends. To avoid spurious significance of the non-agricultural minimum wage (MIN) and the minimum applicable to hired farm labor ($MINA$), time (T) is introduced as a proxy for left-out shifters of demand or supply that might be correlated with the included variables.[4]

With this list of independent variables, reduced-form equations of the hired farm labor market are estimated as follows, using aggregate U. S. data, 1929–1970:

$$
\begin{aligned}
W = & -.26 + \underset{(0.9)}{.28\,PL} + \underset{(5.3)}{1.4\,PK} + \underset{(8.2)}{.053\,WA1} \\
& - \underset{(4.9)}{.013\,WA2} + \underset{(0.6)}{.069\,PX1} - \underset{(0.8)}{.037\,PX2} - \underset{(1.6)}{.002\,T} \\
& - \underset{(1.2)}{.27\,MIN} + \underset{(7.7)}{.85\,MINA}
\end{aligned}
$$

$$
\begin{aligned}
HL = & \, 4071 + \underset{(2.0)}{62\,PL} + \underset{(0.2)}{399\,PK} - \underset{(2.3)}{146\,WA1} \\
& + \underset{(1.7)}{43\,WA2} + \underset{(0.9)}{1040\,PX1} - \underset{(0.7)}{326\,PX2} - \underset{(3.6)}{38\,T} \\
& + \underset{(1.0)}{2338\,MIN} - \underset{(3.9)}{4255\,MINA}
\end{aligned}
$$

W is an index of the farm wage rate and HL is

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[3] To the extent that the general unemployment rate is influenced by minimum wages, the adjusted opportunity wage captures another of their effects, that of keeping from nonfarm employment some farm workers who would otherwise have migrated. However, the existence of non-covered labor markets should vitiate this effect, and in fact the unemployment data are generally taken as dominated by cyclical variation.

[4] Time is measured in years as natural numbers. Thus, the choice of the base year (e.g., 1929 or 1) affects only the intercept term.

the hired labor force in agriculture.[5] The numbers in parentheses are "t" ratios. All monetary variables are deflated by the consumer price index.

Interpretation and Evaluation of Regression Results

The trend component of many of the independent variables inevitably results in high correlation among them, which reduces the precision with which their coefficients can be estimated. The correlation coefficient between $WA1$ and $WA2$ is .994 and between $PX1$ and $PX2$, .993. $WA1$, $WA2$, MIN, W, and HL all have correlation coefficients with T of over .95. Consequently, some of the point estimates of coefficients, notably for past product prices, are not very reliable. Nonetheless, they all have reasonable signs.

The standard errors could be reduced by eliminating some highly colinear variables. However, the issue of interest in this discussion is not the coefficients of these shift variables, but rather the minimum wage variables. Therefore, it is best to include all variables whose exclusion might bias and attribute spurious significance to the coefficients of the minimum wage variables (MIN and $MINA$).

The levels of MIN and $MINA$ have been changed from time to time by legislation and continuously by price level changes. They take the value zero in all years before enactment, and thereafter give the deflated level of the minimum wage in each year. The coefficient of the agricultural minimum ($MINA$) is probably best interpreted as showing its average effect over the years it was in force.

$MINA$, as expected, has a positive coefficient in the W equation and a negative effect on HL; "t" 's are greater than 2.0. The point estimates of the $MINA$ coefficients imply that the 1967 extended minimum wage coverage raised the farm wage rate about 13 percent and that hired farm employment was reduced by about 18 percent from what it would otherwise have been in 1967–70.

The non-agricultural minimum wage variable also acted as expected, though the null hypothesis of a zero coefficient can only be rejected at the 20 percent level. Less precision in the estimated MIN variable has to be expected, since other industries besides agriculture have been available as a "sink" for labor forced out of covered industries, and since the various shifters of equilibrium in non-agricultural covered labor markets were not held constant. In this context it is striking that it was possible to observe as great an effect as the estimated equations show. To get an idea of the magnitude of the effect implied by the point estimates, they indicate that as of 1965 the farm wage rate would have been 7 percent greater had the non-agricultural minima not existed.

In spite of the statistical significance of $MINA$, the possibility exists that the years 1967–70 were abnormal in some other way and that the $MINA$ variable is picking up the effect of this left-out factor. But the shifters of labor market equilibrium usually thought to be most important have been incorporated in the model. There did occur one unique event that was not so incorporated; namely, the elimination of the bracero program (1965), which should also have reduced HL and increased W in the late 1960's. However, the data for Texas and California, the main bracero states, do not show a pattern different enough from the rest of the country to account for the fall in HL and the rise in W that occurred between the early 1960's and 1967–70; indeed, the rate of increase in W and decrease in HL was *smaller* in these two states taken together.[6] It is concluded that $MINA$ is probably not a hidden "bracero program" variable as well as a minimum wage variable.

A second difficulty in interpreting the $MINA$ results arises from the heterogeneity of the hired farm labor force. Even apart from the non-coverage of some employers, those hired workers (presumably the younger and better-

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[5] For years prior to 1962, the data series come from [4]; HL, W, W', and P'' are, respectively, series K-75, K-76, D-628, and K-133. P' was constructed by dividing the value of land and buildings (series K-4) by the acres of land in farms (K-2). Data for years after 1961 are from various annual issues of [3] and [5].

$$WA1 \text{ is } \sum_{i=1}^{5} WA_{t-i} \text{ and } WA2 = WA_{t-1} + 2WA_{t-2} + 3WA_{t-3} + 4WA_{t-4} + 5WA_{t-5}.$$

The coefficients of these variables may be used to estimate the (linear) lag function [1]. $PX1$ and $PX2$ are constructed in the same way.

[6] Some relevant data from [6] are

	Hired Labor Force U. S.	Hired Labor Force Texas	Hired Labor Force California	Hourly Wage U. S.	Hourly Wage Texas	Hourly Wage California
1963	1,782,000	147,000	205,000	.88	.81	1.31
1967–70	1,198,000	96,000	182,000	1.27	1.18	1.73
Percent Δ	−33	−35	−11	44	46	32

educated ones) who already had wage rates above the legislated minimum are unaffected by the minimum wage. Thus, a 1¢ increase in the legislated minimum would never increase the average farm wage rate by 1¢. It follows that the 13 and 18 percent figures above cannot be used to estimate the decline in employment which results from a given change in the *average* farm wage—the elasticity of the demand curve for hired farm labor. What the figures show is the response in aggregate employment to an increase in *some* workers' wage rates. For example, if only one-third of the hired farm labor force is affected directly, the base for the 18 percent is three times too large; the 18 percent is 56 percent of the affected workers. The point is, these results indicate that the elasticity of demand for low-wage farm labor may be quite high compared to that for all hired farm labor taken together, as estimated by Schuh [2] and others.

The issues discussed in the last two paragraphs require more detailed investigation, for example, of regional or state data, before they can be resolved. The present results on the national data, however, seem to provide strong evidence that the extension of U. S. minimum wage legislation to the farm labor market has had a substantial impact on this market and that the consequences have been just as the marginal productivity or neoclassical theory of factor demand predicts.

References

[1] JOHNSON, THOMAS, "A Note on Distributed Lags in Polynomial Form," workshop discussion paper, North Carolina State University, Aug. 1969.

[2] SCHUH, G. EDWARD, "An Econometric Investigation of the Market for Hired Labor in Agriculture," *J. Farm Econ.* 44:307–321, May 1962.

[3] U. S. Department of Agriculture, *Agricultural Statistics*, various issues.

[4] U. S. Department of Commerce, Bureau of the Census, *Historical Statistics of the United States*, Washington, 1960.

[5] ———, *Statistical Abstract of the United States*, various issues.

[6] ———, *Farm Labor*, January 1965 and January 1971.

Impact of Minimum Wages Upon the Level and Composition of Agricultural Employment*

THEODORE P. LIANOS

This paper investigates the effects of minimum wages on agricultural employment in the southern U. S. The principal result was that the introduction of minimum wages decreased the employment of hired and total (hired plus family) labor. Estimates of employment reduction of hired labor due to minimum wages are provided.

THE 1966 AMENDMENT to the Fair Labor Standards Act (FLSA) extended coverage to agricultural workers. Under this amendment farm workers are paid minimum wages when certain conditions are met. Prior to the 1966 amendment minimum wage coverage for farm workers was provided in nine states[1] by state laws, but the various exemptions severely limited the extent of coverage. Federal minimum wage coverage was extended to approximately 400,000 farm workers in 1966 [17, p. 9] and to approximately 520,000 by 1968 [23, p. 9].

To the extent of the author's knowledge the impact of the 1966 amendment on the level and composition of farm employment has not been assessed empirically, although some theoretical discussions related to minimum wages have appeared [6, 14]. The purpose of this study is to investigate the effect of the 1966 amendment on the employment of hired farm workers and total farm employment. Only secondary consideration will be given to the question of substitution of family labor for hired labor.

Where the existing wage rate was already higher than the federal minimum, the 1966 amendment has had no effect. Among the regions where minimum wages are effective, the effects are expected to be observed most clearly in the southern states and consequently the southern region was chosen for the experimental units.

The relevant parts of the 1966 amendment include the stipulation requiring the minimum wage rate to be paid for agricultural employment and the conditions requiring payment of minimum wages. The actual minimum wages are specified as follows: $1.00 per hour as of Feb. 1, 1967; $1.15 per hour as of Feb. 1, 1968; and $1.30 per hour as of Feb. 1, 1969. The minimum wage coverage is extended to workers employed only on farms that used more than 500 man-days of agricultural labor during any calendar quarter of the preceding year. "Man-day" is defined as any day in which a worker performs at least one hour of agricultural work.

Certain categories of workers are not covered even though they are employed by farms that meet the 500 man-days requirement. The most important category includes members of the employer's family who are also excluded from the man-day count. Other categories excluded from minimum wage coverage are hand harvest workers paid piece rates for work generally recognized as piece work in the area, migrant hand harvest workers 16 years of age or under and employed on the same farm as their parents, and workers principally engaged in range production of livestock. Some qualifications imposed on workers paid piece rates and harvest workers under 17 years of age are not important for the problem at hand. Hand harvest workers are paid piece rates and workers in range livestock production are not included in the man-day count.

This brief statement of the relevant parts of the 1966 amendment to the FLSA can serve as a guide in the investigation of changes that followed the amendment.

Some Effects of Minimum Wages on Employment

With respect to the effects of minimum wages on the level of employment, economic theory suggests that a decline in employment is to be expected. This is the result of two negative effects: a direct effect as employers tend to substitute non-labor inputs for labor, which be-

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[1] Arkansas, California, Hawaii, Massachusetts, Michigan, New Jersey, New Mexico, Oregon, and Wisconsin.

THEODORE P. LIANOS *is assistant professor of agricultural economics and assistant agricultural economist in the experiment station and on the Giannini Foundation, University of California, Davis.*

comes relatively expensive, and an indirect effect through substitution in consumption as the product produced by the labor receiving the minimum wage becomes relatively expensive. There seems to be no disagreement with the validity of this reasoning as long as it is assumed that no other changes with offsetting results are taking place. The controversy, unnecessary in the author's opinion, arises when the question of the quantitative importance of the effects and validity of the *ceteris paribus* assumption is considered. However, this is a question which can be answered on the basis of empirical investigation rather than on the basis of theoretical speculation.[2] The agricultural sector throughout the period covered in this study (1950–1969) has been characterized by rapid application of technological advancement which has resulted in an increasing capital-labor ratio and a reduction of employment. The question with regard to the effect of minimum wages is whether the reduction in farm employment has been accelerated as a result of the imposition of minimum wages.

With respect to the effect of legal minimum wages on the composition of agricultural employment, a guide is provided by the conditions which have to be met for the payment of a minimum wage. Since members of the employer's family are excluded from coverage, employers have an incentive to substitute family labor for hired labor as long as the opportunity cost of each family member is less than the minimum wage to be paid for a hired worker. An additional incentive for family labor-hired labor substitution is given by the exclusion of family workers in the man-day count. Thus, it is possible for many farms not only to reduce the payroll by utilizing family labor but also to avoid payment of minimum wages altogether. As a result of the exclusion of family workers from both the minimum wage payment and the man-day count, one would expect a reduction in the ratio of hired labor to family labor.

[2] Within the framework of profit maximization, there exists a theoretical possibility that imposition of minimum wages would increase the level of employment in a monopsonistic labor market, but this case is considered of little practical importance [9, pp. 189–190]. In the analysis of the agricultural labor market this possibility can be safely neglected. Under alternative assumptions of firm behavior minimum wages may have no employment effect. For example, in the case of satisficing entrepreneurs no employment reduction should be expected as long as minimum wages do not reduce the level of satisfaction of the satisficing entrepreneur below a predetermined minimum.

The family labor exclusion would also tend to reduce the significance of the negative effect of minimum wages on total agricultural employment. This of course would depend on the ease of family labor-hired labor substitution which in turn would depend mainly on the size distribution of firms and on the opportunity cost of family labor.

To summarize, as a result of the imposition of effective minimum wages on the agricultural sector, one would expect a reduction in the employment of hired workers, a reduction in total farm employment, and a reduction in the ratio of hired workers to family workers.

The findings of recent research on the U. S. nonfarm sector tend to support the hypothesis that effective minimum wage laws reduce employment, and if employment is increasing (decreasing) minimum wages would reduce (increase) the rate of increase (decrease). The hypothesis that minimum wages would penalize marginal workers such as teenagers and nonwhites, i.e., change the composition of employment, has also received support. Studies by Brozen [3, 4], Campbell and Campbell [5], Easley and Fearn [7], Kaun [12], Shkurti and Fleisher [15], and Kosters and Welch [13] tend to give empirical substantiation to these hypotheses, although studies with contrary results are not absent [1, 8, 11].

Demand for Hired Farm Labor

In studying the employment effects of the minimum wage, some authors have examined employment changes, while others have examined unemployment rate changes. In this study, attention is directed to employment level changes for two reasons: first, minimum wages would affect directly the level of employment rather than unemployment, unless the assumption is made that the supply curve of labor is stable; second, information on unemployment of farm laborers is not available.

Demand equations

This analysis is based on three demand-for-labor equations. The first equation based on a Cobb-Douglas production function has the form

$$\frac{L_t}{PQ_t} = a_1\left(\frac{1}{w_t}\right) \tag{1}$$

where L = labor, PQ = value added, and w = wage rate. In addition to the well-known

restriction that this function imposes on the elasticity of substitution, namely, that it is unity, it implies a wage elasticity of demand for labor greater than one. To avoid these difficulties, a demand-for-labor equation based on a constant elasticity of substitution production function was derived. The derived equation takes the form

$$\ln L_t = a_0 + a_1 \ln w_t + a_2 \ln Q_t + a_3 \ln t. \tag{2}$$

The third demand equation[3] assumes a Nerlove-type adjustment process and is specified as,

$$\begin{aligned} \ln L_t = a_0 + a_1 \ln L_{t-1} + a_2 \ln Q_t \\ + a_3 \ln\left(\frac{1}{w_t}\right) + a_4 \ln t. \end{aligned} \tag{3}$$

To each of the above three equations is added the independent variable (X_1-X_2) which is obtained by letting

$$\begin{aligned} X_1 &= 1 \quad \text{for 1950–1965} \\ &= 0 \quad \text{otherwise} \\ X_2 &= 1 \quad \text{for 1966–1969} \\ &= 0 \quad \text{otherwise.} \end{aligned}$$

The significance and direction of the impact of the minimum wage law is to be tested by the coefficient of (X_1-X_2) because it provides information on the effect of the two periods on the level of farm employment, *ceteris paribus*. Since the major relevant change separating the two periods is the absence of minimum wages in the first period and its presence in the second, any effect of (X_1-X_2) can be attributed to the introduction of legal minimum wages. Given that the restriction imposed on the coefficients of X_1 and X_2 is $b_1+b_2=0$, the variable (X_1-X_2) is equal to 1 for the years 1950–1965 and equal to -1 for the years 1966–1969. Consequently, a positive and significant coefficient of (X_1-X_2) would suggest that minimum wages had a significant and negative effect on farm employment. The opposite effect would be indicated by a negative and significant coefficient of (X_1-X_2). An insignificant coefficient, i.e., not different from zero in the statistical sense, would imply that minimum wages had no effects of quantitative importance.

Although the federal minimum wage legislation did not become effective before 1967, the 1966 year has been included in the post-minimum wage period in order to take account of possible announcement effects, since the idea of extending minimum wages to agriculture had been discussed before 1966. The announcement effect would be stronger in the case of family labor-hired labor substitution than in the case of nonlabor-labor input substitution.

Data

It has been indicated that the effects of the minimum wage legislation would be most noticeable in the southern regions of the U. S. According to the enumerative survey of USDA in 1965, of all hired farm workers employed on farms using 300 or more man-days of hired labor in a peak quarter of the previous year and receiving less than $1.00 per hour, 83 percent were employed in the South, and 8, 4, and 2 percent in the North Central, Northeast, and West, respectively [22, p. 46]. The same survey also showed [22, p. 49] that in 1965 the percent of hired workers employed on farms specified as above and receiving less than $1.00 per hour was 69 in the South, 20 in the Northeast, 35 in the North Central, and 7 in the West. These estimates clearly indicate that if the introduction of a legal minimum wage has had any effect on farm employment, the effect would be most noticeable in the South. Consequently, data from southern states seem appropriate in an attempt to evaluate the effects of minimum wages. Although the man-days criterion for the applicability of the minimum wage law was changed from 300 to 500 man-days, the appropriateness of the South as the experimental unit does not change. The 1968 enumerative survey [23, p. A-20] also showed that the percent of hired workers on farms employing 500 or more man-days and receiving less than $1.20 per hour was 51.4 in the South, 5.1 in the Northeast, 12.8 in the North Central, and 4.3 in the West. Clearly, the South appears to be the most vulnerable region, whether the limit is 300 or 500 man-days.

The data used for the estimation of equations (1), (2), and (3) are time series on labor input, value added, and wage rate in agriculture for the 1950–1969 period. Labor employment (L) is measured by the annual average number of hired workers who did farm work for pay during the survey weeks. It includes farm family members who received cash wages for their work on family farms. This series is reported in [17] for the period 1950–1959, in [18] for 1960–

[3] This equation is similar to that used by Tyrchniewicz and Schuh [16, p. 777]. We have substituted value added for real farm prices and dropped operator labor since its coefficient was not different from zero.

1962, and in [19] for 1963–1969. Value added was defined as the sum of (Cash Receipts + Home Consumption + Net Changes in Inventories + Government Payments) − (Total Operating Expenses except for Hired Labor) − (Property Taxes). Data for all these items are available in [20] and [21]. The farm wage rate is measured by the composite wage rate per hour as reported in the various issues of [19].

Twelve southern states form three regions: (1) Southern Plains, including Kentucky, North Carolina, Tennessee, Virginia, and West Virginia; (2) Southeast, including Alabama, Florida, Georgia, and South Carolina; and (3) Delta States, including Arkansas, Louisiana, and Mississippi. The measure of the wage rate used in the estimation of the model is a weighted average of wage rates in the states of each region, with employment in each state used as a weight. The series on operating expenses, property taxes, and wages are deflated by the index of prices paid by farmers (1957–1959 = 100). Gross output (cash receipts, etc.) is deflated by the index of prices received by farmers (1957–1959 = 100).

Estimation

The results of estimating equations (1), (2), and (3) for each of the three regions are reported in Tables 1, 2, and 3, respectively. Equations (1) and (2) were estimated by ordinary least squares, while equation (3) was estimated by a two-stage least squares procedure [10, p. 41] by substituting $\ln \hat{L}_{t-1}$ for $\ln L_{t-1}$ where $\ln \hat{L}_{t-1}$ is the predicted value of $\ln L_{t-1}$ based on the other independent variables.

Considering first the coefficients of the dummy variable ($X_1 - X_2$), which is the pri-

Table 1. Estimates of demand for hired labor, equation 1

Variables	Demand for Labor $(L+PQ)^a$		
	Southern Plains	Delta States	Southeast
w = inverse of wage rate	.079* (.003)	.093* (.006)	.075* (.004)
X_1-X_2 = dummy variable	.018* (.005)	.035* (.011)	.019** (.007)
$\bar{R}^2$	.77	.70	.71
d.f.	18	18	18
D-W	.82	.66	.89

a Standard errors are presented in the parentheses. One, two, and three asterisks indicate significance at .01, .05, and .10 levels, respectively.

Table 2. Estimates of demand for hired labor, equation 2

Variables	Demand for Labor $(L)^a$		
	Southern Plains	Delta States	Southeast
Constant	3.708	5.501	5.675
Q = value added	.148 (.196)	−.054 (.106)	−.102 (.132)
W = wage rate	−1.371* (.311)	−.359 (.207)	−.483** (.238)
X_1-X_2 = dummy variable	.065** (.030)	.177* (.031)	.105* (.032)
t = time	.012 (.029)	−.070** (.027)	.028 (.031)
$\bar{R}^2$	.93	.95	.91
d.f.	15	15	15
D-W	2.3	1.73	.89

a Standard errors are presented in the parentheses. One, two, and three asterisks indicate significance at .01, .05, and .10 levels, respectively.

Table 3. Estimates of demand for hired labor, equation 3

Variables	Demand for Labor $(L)^a$		
	Southern Plains	Delta States	Southeast
Constant	.618	3.313	5.228
L_{t-1} = lagged dependent variable	.704* (.20)	.384* (.127)	.237 (.263)
Q = value added	.148 (.177)	−.003 (.103)	.172 (.154)
W = inverse of wage rate	.037** (.017)	−.007 (.007)	.008 (.015)
X_1-X_2 = dummy variable	.064** (.024)	.166* (.026)	.123* (.031)
t = time	−.037 (.032)	−.086* (.029)	.013 (.048)
$\bar{R}^2$	.95	.96	.89
d.f.	13	13	13
D-W	1.89	1.26	1.03

a Standard errors are presented in the parentheses. One, two, and three asterisks indicate significance at .01, .05, and .10 levels, respectively.

mary concern of the paper, it appears that it is positive and significant in all nine cases (three equations for each of the three regions). Thus, the specification of the demand equation seems to have no effect on the conclusions to be derived from the dummy variable. In fact, in equations (2) and (3) the coefficients are approximately equal in value. These results lend support to the hypothesis that imposition of effective minimum wages tends to reduce the level of employment. Of course, the level of employment has been declining throughout the period under examination, but the coefficient of X_1-X_2 is believed to be free of serious biases resulting from other sources in the system that lead to declines in employment.

The coefficients of the wage rate variable may be used to derive estimates of the wage elasticity of demand for hired labor. Using $e_L = -1/1-a_1$ and the estimates of a_1 from Table 1, the wage elasticity of labor demand is found to be approximately equal to -1.1 for all three regions. From Table 3, for Southern Plains, the only region with a significant coefficient, the elasticity is equal to -1.04 in the short run and equal to -3.51 in the long run. From Table 2, the wage elasticity of demand for labor[4] is -1.371 for the Southern Plains and $-.483$ for the Southeast. These estimates tend to suggest that the elasticity of demand for labor is probably greater than unity, particularly in the long run.[5]

The coefficients of the other variables are of less interest for the purposes of this study. The adjustment coefficient for the two regions where they are significant are .296 for the Southern Plains and .616 for the Delta States. The coefficient for the value added variable is insignificant in all six regressions of Tables 2 and 3. Finally, the trend variable has a significant and negative coefficient in the regressions referring to the Delta States. It has been suggested [16] that this may reflect the effects of technical change, changes in the quality of labor, or consistent measurement errors in the other variables (or any combination of these).

[4] It can be easily shown that for a CES production function the wage elasticity of the demand for labor is equal to the negative of the elasticity of substitution, i.e., $e_L = -\sigma$.

[5] Other estimates of e_L are available in the literature. Wallace and Hoover [24], Bauer [2], and Tyrchniewicz and Schuh [16] have found e_L equal to -1.433, -1.482, and $-.261$ ($-.492$ in the long run), respectively. Our estimates seem to be in agreement with the first two, except for one ($-.483$), which is very close to the long-run elasticity of [16].

Employment reduction due to minimum wages.—The estimates presented in Tables 1, 2, and 3 indicate that minimum wages have reduced the level of employment. Some estimates are now presented regarding the amount of reduction of employment of hired farm workers. The procedure is, first, estimate what the wage rate would have been if minimum wages had not been introduced. Two such estimates were obtained for each year of the 1967–1969 period: one (w_1) is based on the assumption that wages would increase according to the average increase of the last four years, i.e., 1963–1966; the other estimate (w_2) is based on the assumption that the yearly increase will be equal to that of the last year. These estimated wage rates are then introduced into regression equations (2) along with the values of the other independent variables for the corresponding year, and the quantities of labor demanded are obtained ($\hat{L}_1$ and $\hat{L}_2$). To find the reduction in employment due to minimum wages, the level of employment corresponding to the wage rate actually paid must be known. Two levels of employment were used: one (L_e) was found by introducing the actual wage rates in the estimated regressions, which is of course the predicted value of hired labor; the other estimate used is the level of employment actually observed (L_a). Thus, the differences ($\hat{L}_1-L_e$) and $\hat{L}_1-L_a$) are estimates of the reduction in employment due to minimum wages. The results are presented in Table 4, which is self-explanatory. The only clarification needed is that the estimated reductions in employment are cumulative. For example, for the Southern Plains, assuming that the wage rate would have been .6990, the reduction in employment due to minimum wages is estimated to be 11,100 workers in 1967 (column 3). For the two-year period (1967–1968) it is 23,400. One may obtain the reduction during the second year (1968) by subtraction ($23.4-11.1=12.3$). Considering (L_1-L_a) for the whole period (1967–1969), the table shows that the percentage of total employment reduction due to minimum wages varies from 24 to 51. These results leave no doubt about the importance of the negative minimum wage effects on employment.

Demand for Total Farm Labor

To estimate the demand equation for total labor the same equations as for hired labor, namely, equations (1), (2), and (3), are used. The employment variable is of course changed

Table 4. Estimates of reduction of employment of hired labor due to minimum wages

	Southern Plains 1967	1968	1969	Delta States 1967	1968	1969	Southeast 1967	1968	1969
		w_1			w_1			w_1	
	.6990	.7167	.7344	.6705	.6883	.7061	.6864	.7163	.7462
					(thousands)				
(1) $\hat{L}_1$ = estimated employment	202.1	193.4	189.4	129.9	128.3	127.2	157.0	154.2	150.2
(2) $\hat{L}_1 - L_e$ = reduction due to minimum wages	8.4	10.7	35.8	6.0	7.4	13.3	3.1	6.7	12.0
(3) $\hat{L}_1 - L_a$ = reduction due to minimum wages	11.1	23.4	33.4	13.9	8.3	5.2	2.0	8.2	9.2
(4) Percent: (3) ÷ (9)	37	46	51	48	55	40	40	59	48
		w_2			w_2			w_2	
	.7176	.7539	.7902	.6699	.6871	.7043	.7006	.7457	.7908
					(thousands)				
(5) $\hat{L}_2$ = estimated employment	194.8	180.4	171.4	129.9	128.4	127.4	155.4	151.3	146.1
(6) $\hat{L}_2 - L_e$ = reduction due to minimum wages	1.1	−2.3	17.8	6.0	7.5	13.5	1.5	3.4	5.9
(7) $\hat{L}_2 - L_a$ = reduction due to minimum wages	3.8	10.4	15.4	13.9	8.4	5.4	.4	5.3	5.1
(8) Percent: (7) ÷ (9)	13	20	24	48	55	41	8	38	27
(9) Total reduction in employment, L_a (thousands)	30.0	51.0	65.0	29.0	15.0	13.0	5.0	14.0	19.0

to include family labor, but the other variables are the same. It may be noted, with respect to wages, the author's assumption is that the market wage rate is applicable to family labor as well as hired labor. The regression equations obtained are reported in Tables 5, 6, and 7. The results and their interpretation are similar to those of Tables 1, 2, and 3. The only discomforting and difficult to explain result is the negative and significant coefficient of value added for the Southeast. The coefficients of the dummy variable are positive and significant in all cases, thus supporting the hypothesis under test. From these results the interested reader may easily derive coefficients of adjustment and various elasticities.

Given that employment of both total and hired labor has been reduced as a result of minimum wages, the only statement one can make is that if family-hired labor substitution has taken place it has been a partial one,[6] because if it were complete (one family member for one hired worker) total employment would not have been reduced. Alternatively, these results are consistent with constant, diminishing, or increasing employment of family labor (but not increasing by the same amount that hired labor is decreasing). Thus, under the present model the question of substitution can only be partially answered.

Although the question of family-hired labor substitution clearly requires further investigation, it is not the author's intention to do so in the present paper. This would involve answering questions relating to the structure of the agriculture industry which fall outside the scope of this study. For example, questions on the relationship between profit per farm and size of farm, mechanization and farm size, composition of employment and farm size would have to be investigated.

Summary of the Results and Some Implications

The main burden of the economic adjustments made in response to the imposition of minimum wages has been borne by hired workers whose employment was reduced. As-

Table 5. Estimates of demand for total labor, equation 1

Variables	Demand for labor $(L+PQ)$[a] Southern Plains	Delta States	Southeast
w = inverse of wage rate	.364* (.026)	.307* (.035)	.244* (.028)
$X_1 - X_2$ = dummy variable	.098** (.043)	.123** (.061)	.085*** (.049)
$\bar{R}^2$	.58	.50	.50
d.f.	18	18	18
D-W	.26	.32	.36

[a] Standard errors are presented in the parentheses. One, two, and three asterisks indicate significance at .01, .05, and .10 levels, respectively.

[6] Independent data suggest that if substitution has occurred, probably it was not in the form of more hours of work per family worker [19].

Table 6. Estimates of demand for total labor, equation 2

Variables	Demand for labor (L)[a]		
	Southern Plains	Delta States	South-east
Constant	6.673	7.98	8.44
Q = value added	.011 (.168)	−.198 (.133)	−.261** (.126)
W = wage rate	−1.112* (.268)	−.482** (.260)	−.348 (.228)
X_1-X_2 = dummy variable	.048*** (.025)	.084** (.038)	.092* (.031)
t = time	−.124* (.026)	−.221* (.038)	−.148* (.031)
$\bar{R}^2$	.97	.96	.97
d.f.	15	15	15
D-W	1.25	.85	1.31

[a] Standard errors are presented in the parentheses. One, two, and three asterisks indicate significance at .01, .05, and .10 levels, respectively.

Table 7. Estimates of demand for total labor, equation 3

Variables	Demand for labor (L)[a]		
	Southern Plains	Delta States	South-east
Constant	4.238	5.997	6.227
L_{t-1} = lagged dependent variables	.279* (.121)	.215** (.103)	.336* (.093)
Q = value added	.175 (.169)	−.057 (.118)	−.235** (.094)
W = inverse of wage rate	.035** (.015)	−.002 (.007)	−.003 (.008)
X_1-X_2 = dummy variable	.069* (.020)	.104* (.026)	.089* (.017)
t = time	−.206* (.032)	−.295* (.035)	−.136* (.037)
$\bar{R}^2$	.97	.97	.98
d.f.	13	13	13
D-W	1.40	.90	1.14

[a] Standard errors are presented in the parentheses. One, two, and three asterisks indicate significance at .01, .05, and .10 levels, respectively.

suming no increase in alternative employment opportunities, the implication is that income redistribution has occurred: those remaining employed are receiving higher wages and consequently are better off, whereas those whose employment was reduced are receiving less and are worse off. Therefore, no statement can be made with regard to the welfare effects of minimum wages. It is true, however, that according to this study's results the cost of adjustment to minimum wages is paid by some of those whom the 1966 amendment intended to help economically.

Some of the studies on minimum wages [3, 4, 7, 8] suggest that the incidence of unemployment is not distributed randomly over all workers, but that increases in unemployment are associated with marginal or less productive workers. Marginal or peripheral workers are usually identified as teenagers, older people, and nonwhites. Assuming that this is also true for the agricultural sector, the negative employment effect of minimum wages is becoming more serious as marginal workers are the least prepared to obtain and keep a nonfarm job.

Since both the employment of total and hired labor has decreased, there is little that can be deduced about family-hired labor substitution. If such substitution has occurred, however, family labor has replaced only a part of the discharged hired labor.

References

[1] BARTH, PETER, "The Minimum Wage and Teen-Age Unemployment," Proceedings of the Twenty-Second Annual Winter Meeting, Industrial Relations Research Association, New York, Dec. 1969.

[2] BAUER, L. L., "The Effect of Technology on the Farm Labor Market," *Am. J. Agr. Econ.* 51:505–518, Aug. 1969.

[3] BROZEN, YALE, "Minimum Wage Rates and Household Workers," *J. Law & Econ.* 2:103–109, Oct. 1962.

[4] ———, "The Effect of Statutory Minimum Wage Increases on Teen-Age Employment," *J. Law & Econ.* 9:109–122, April 1969.

[5] CAMPBELL, C. D., AND R. C. CAMPBELL, "State Minimum Wage Laws as a Cause of Unemployment," *Southern Econ. J.* 35:323–332, April 1969.

[6] COFFEY, J. D., "National Labor Relations Legislation: Possible Impact on American Agriculture," *Am. J. Agr. Econ.* 51:1065–1074, Dec. 1969.

[7] EASLEY, J. E., AND R. M. FEARN, "Minimum Wages and Unemployment of Teen-Agers," unpublished paper, Department of Economics, North Carolina State University, 1970.

[8] FOLK, HUGH, "The Problems of Youth Unemployment," *The Transition from School to Work*, Princeton

Manpower Symposium, Princeton, N. J., May 9–10, 1968, pp. 76–107.

[9] FRIEDMAN, MILTON, *Price Theory, A Provisional Text*, Chicago, Aldine Publishing Co., 1962.

[10] GRILICHES, ZVI, "Distributed Lags: A Survey," *Econometrica* 35:16–49, 1967.

[11] KAUFMAN, J. J., AND T. G. FORAN, "The Minimum Wage and Poverty," in *Towards Freedom from Want*, eds., S. A. Levitan, W. J. Cohen, and R. J. Lampman, Wisconsin, Industrial Relations Research Association, 1967.

[12] KAUN, D. E., "Minimum Wages, Factor Substitution, and the Marginal Producer," *Quart. J. Econ.* 79:478–486, Aug. 1965.

[13] KOSTERS, M., AND F. WELCH, *The Effects of Minimum Wages on the Distribution of Changes in Aggregate Employment*, Rand Corporation, RM-6273-OEO, Sept. 1970.

[14] MAIER, F. H., "The Incidence of Increasing Wage Costs in Farm Production," *J. Farm Econ.* 43:1193–1200, Dec. 1961.

[15] SHKURTI, W. J., AND B. M. FLEISHER, "Employment and Wage Rates in Retail Trade Subsequent to the 1961 Amendments of the Fair Labor Standards Act," *Southern Econ. J.* 35:37–48, July 1968.

[16] TYRCHNIEWICZ, EDWARD W., AND G. EDWARD SCHUH, "Econometric Analysis of the Agricultural Labor Market," *Am. J. Agr. Econ.* 51:770–787, Nov. 1969.

[17] U. S. Department of Agriculture, Statistical Reporting Service, *Farm Employment*, Stat. Bull. 334, Washington, 1963.

[18] ———, Agricultural Marketing Service, *Farm Labor*, Washington, March 1963.

[19] ———, Agricultural Marketing Service, *Farm Labor*, Washington, January 1964–1970 issues.

[20] ———, Economic Research Service, *Farm Income State Estimates, 1949–1968*, FIS 214 Supplement, Aug. 1969.

[21] ———, ERS, *Farm Income Situation Supplement*, Aug. 1970.

[22] ———, *Hired Farm Workers: A Study to Evaluate the Feasibility of Extending the Minimum Wage Under the Fair Labor Standards Act*, submitted to the U. S. Congress, Jan. 1966.

[23] U. S. Department of Labor, Wage and Hour and Public Contracts Division, "Hired Farmworkers: A Study of the Effects of the $1.15 Minimum Wage Under the Fair Labor Standards Act," *Economic Effects Studies*, 1969.

[24] WALLACE, T. D., AND D. M. HOOVER, "Income Effects of Innovation: The Case of Labor in Agriculture," *J. Farm Econ.* 48:325–336, May 1966.

Farmer Conservatism and the Incidence of Taxes*

J. Ronnie Davis and Charles W. Meyer

State sales and income taxes and local property taxes generally absorb a higher percentage of the income of farmers than of nonfarmers, according to an Iowa incidence study. Simple models of voting behavior show higher tax burdens may cause farmers to be more conservative toward public spending than other taxpayers, even though their demand for public services is identical.

Farmers have been prominent participants in the recent "taxpayers' revolt." They object to increases in public expenditures, especially for schools. In Iowa, for example, rural legislators were in the vanguard as the legislature imposed a temporary freeze on school spending, trimmed millions from the governor's budget requests, and transferred part of the cost of school finance from property to income taxes.

Opposition of farm owner-operators to rising property taxes is to be expected, but opposition to higher spending at a time when a part of the tax burden is being transferred from property to other tax bases requires explanation. Does it mean that farmers are generally more conservative than urban residents in their attitude toward public spending, or that they continue to bear more than their "fair share" of the tax burden even after significant changes in the tax structure?

Most discussions of tax policy focus on ability-to-pay criteria, but in a democracy the attitude of major voting blocs toward their share of benefits and costs can put constraints on tax and expenditure policies. The authors hypothesize that the distribution of tax burdens may be a more important determinant of farmers' attitudes toward public spending than their demand for public services. After presenting two simple models of voter behavior, the implications of the results of an Iowa tax incidence study are examined.

Models of Voting Behavior[1]

In model A it is assumed that there are three voters, or three equal-sized groups of voters (say, farmers, businessmen, and wage earners), with different levels of demand, D_1, D_2, and D_3, for public services, as measured on the Q axis in Figure 1. Each voter (or group of voters) pays the same price, P_1 per unit of public services.[2] Groups 1, 2, and 3 favor Q_1, Q_2, and Q_3 units of public services, respectively. If they vote on the same level of services to be provided, all will favor providing at least Q_1; two-thirds will vote to expand output to Q_2; one-third to Q_3; and none beyond Q_3. Under majority rule output will be extended to but not beyond Q_2.[3] If farmers paid the same tax price per unit of public good, their opposition to existing levels of spending would be consistent with a low level of demand for public services, as indicated by D_1 in Figure 1.

In model B it is assumed that all voters have identical demand for public services, D in Figure 2, but that the tax base is allocated unequally among three voters or equal-sized groups. The highest tax price is P_1 per unit, paid by, say, farmers. Businessmen pay P_2 and wage earners pay P_3. Again, group 1 (farmers)

* The authors wish to thank W. H. Foeller for computational assistance.

[1] Our discussion draws heavily on the pioneering efforts of Bowen [2]. We make the simplifying assumptions that demand for public services is unaltered by the income effect of alternative tax schemes and that the cost per unit is constant.

J. Ronnie Davis *is associate professor of economics at the University of Florida and* Charles W. Meyer *is professor of economics at Iowa State University.*

[2] We beg the question of measuring the output of tax-financed public services, since it is not of vital concern to our main point.

[3] Duncan Black [1, pp. 14–16] demonstrated that under majority rule with an odd number of voters the outcome will coincide with that favored by the median voter. In model A voter (group) 2 is in equilibrium, while the others are in disequilibrium.

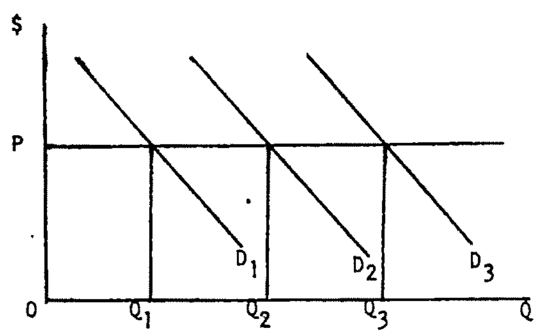

Figure 1. Voters with different levels of demand for public services

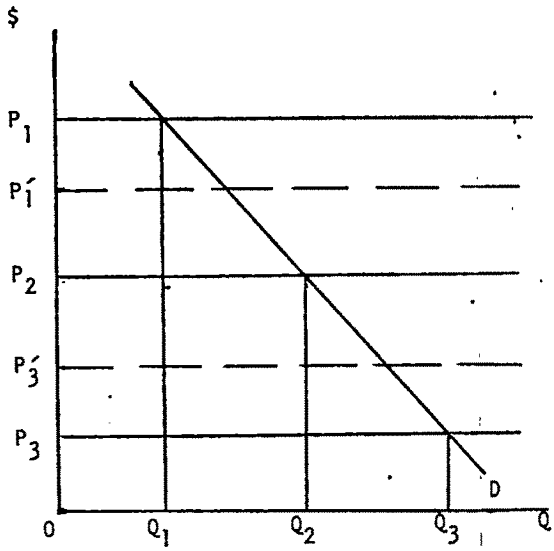

Figure 2. Voters with identical demand for public services

will take a conservative view of public spending, but in this model it is due to the tax structure, not to a difference in demand for public services.

Apparent preferences would be reversed if the tax structure could be changed so that farmers paid the lowest tax price and wage earners the highest. It seems unlikely, however, that realistic changes in the tax structure could bring about such a reversal. A shift in emphasis from property to income or sales taxes might change relative tax prices somewhat, e.g., to P_1' and P_3' in Figure 2, but even after such a change, farmers would appear to hold conservative views on public spending. The results of this tax incidence study indicate that, at least in Iowa, even if a major change is made in the tax structure, farm operators will still pay a relatively higher tax price for public services and will therefore tend to favor lower public outlays than other groups.

Tax Incidence by Occupation

The estimated incidence of the property tax in Iowa is shown in Table 1.[4] Column 1 shows average net tax burden as a percentage of income across income groups. Only that portion of the property tax burden actually absorbed by Iowa residents is reflected in the percentages. The concepts of income and net burden and the shifting assumptions used in deriving incidence estimates for property and other taxes are described in the appendix. Column 2 of Table 1 shows the average property tax incidence of farm owner-operators who own all of their land. As expected, the percentages exceed the statewide average, especially in the low and middle income categories. This comparison may be somewhat misleading, because many operators rent part or all of the land they farm. Hence, the tax burden on the typical farmer may be somewhat less than the figures indicate.

More surprising, perhaps, is the indication that state personal income and sales taxes generally absorb a larger percentage of the income of farmers than of non-farmers, as shown in Table 2. The relatively high income tax rates on farmers with incomes over $10,000 are particularly noteworthy. These figures may be somewhat misleading, however. Farmers are likely to deduct as business expenses outlays that other taxpayers either cannot deduct or treat as itemized personal deductions. This would tend to introduce an upward bias in the incidence percentage for farmers, since the authors' income estimates are derived in part from adjusted gross income as reported on state returns. It seems improbable, however, that this source of bias accounts for the entire differential between farmers and others, especially since some of the same opportunities are open to the nonfarm self-employed. Thus, it must be concluded that within income groups and in total farmers bear at least their proportionate share of the cost of public services financed by the state income tax.

Incidence figures for the 3 percent Iowa sales tax (Table 2) reveal that farmers pay a higher

Table 1. Incidence of Iowa property tax, 1969, as percent of income paid in tax

Money Income (Thousands of Dollars)	All Iowa Residents	Farm Owner-Operators[a]
	percent	
0–3	8.6	34.8
3–5	6.2	20.0
5–7	5.1	17.8
7–10	3.8	17.6
10–15	3.4	10.6
15–20	3.8	6.4
20–25	3.3	5.6
Over 25	3.9	5.8
Average	5.9	14.2

[a] Assumes farm owner-operators own all of their land.

[4] The term "incidence" has no generally accepted definition in the public finance literature. We define it as the net reduction of money income of a taxpayer that is due to the tax.

Table 2. **Incidence of Iowa personal income and sales taxes by income and occupation group, 1969, as percent of income paid in tax**

Money Income (Thousands of Dollars)	Occupation of Household Head			
	Wage and Salaried	Self-Employed	Farmers	Retired
		percent		
1. *Income Tax*				
0–3	0	0	0	0
3–5	0.5	0.2	0.3	0.1
5–7	0.9	0.6	0.8	0.5
7–10	1.1	1.0	1.3	0.8
10–15	1.3	1.3	1.8	1.3
15–20	1.4	1.6	2.2	1.5
20–25	1.5	1.7	2.3	1.6
Over 25	1.6	1.6	2.3	1.6
Average	1.1	1.4	1.4	0.5
2. *Sales Tax*				
0–3	2.5	3.0	6.0	2.1
3–5	2.3	3.0	3.8	2.0
5–7	2.2	2.6	3.2	1.9
7–10	1.9	2.2	2.2	1.8
10–15	1.8	2.0	1.6	1.7
15–20	1.4	1.6	1.5	1.3
20–25	1.1	1.3	1.4	1.0
Over 25	0.9	1.6	0.7	0.8
Average	1.9	1.8	2.6	1.9

percentage of their income in sales taxes than do members of the other three occupational groups. Among income groups this relationship holds except in the over $25,000 group. The higher percentage paid by farmers is due primarily to the sales tax they pay on selected business purchases, including farm machinery, motor vehicles, and a variety of repair services.

Also of interest is the apparently great regressivity of the sales tax on farmers. This characteristic is traceable to family consumption expenditures. Outlays on sales-taxed consumer goods by families in the various income-occupation groups are derived from the 1960–61 Survey of Consumer Expenditures [7, 8]. Survey results are classified according to income earned in the year of the study. Davies [3] has shown that use of annual income rather than permanent income (approximated by averaging income backward with declining weights over previous years) leads to greater regressivity of sales tax incidence patterns. This is to be expected, since families tend to adjust their consumption to permanent income. At the lower end of the income scale families with observed incomes below permanent income tend to predominate; the reverse occurs at the upper end of the scale. Since farm income generally fluctuates more than income of other major occupational groups, the regressive bias in sales tax estimates is accentuated among farm families.

Regressivity patterns for the property tax may be subject to the same sort of bias, especially among farmers, because allocations of tax burdens among income groups are based on an asset survey that relates ownership of taxable property to money income received in the year preceding the study.[5] No attempts have been made to adjust for the regressive bias in incidence patterns, since the bias does not appear to affect the authors' main contention, namely, that in Iowa farm operators are generally subjected to tax rates equal to or greater than those imposed on other major occupational groups under any of the three major sources of tax revenue.

Conclusions

This paper attempts to demonstrate that Iowa farmers generally pay a percentage of their income for the public services of state and local governments that is as high as or higher than that paid by members of other occupational groups. This relationship holds in total and within most income groups. Therefore, the generally conservative position taken by rural-area representatives toward public expenditures *may* be the result of differences in the tax price that their farm constituents pay for such services. Only if farmers have a stronger preference for public services than members of other occupational groups would they be expected to support comparable expenditure levels. Moreover, it is unlikely that marginal changes from property to sales-income tax finance would change either the relative tax burdens on Iowa farmers or the direction of their preferences. An exception might arise for those expenditures that are of benefit primarily to farmers, such as rural roads. (Iowa is near the top in per capita expenditure on roads and highways.)

APPENDIX

Impact and Shifting Assumptions

The impact of the retail sales tax is assumed to be on the buyer with the retailer acting as a collection agent. Seventy-five percent of the sales tax collected is allocated to consumers

[5] See [5, pp. 16–26] for a description of the survey. Property tax allocations in the higher income brackets are based on farm records owing to the thinness of the survey sample.

with the remainder being allocated to various business categories, primarily on the basis of data collected by the Iowa Department of Revenue. The 75 percent figure is in line with that for other states with a comparable sales tax base, as shown by Fryman and references he cites [4]. The impact of property and personal income taxes is assigned, respectively, to property owners and income recipients.

Shifting of taxes depends on such things as the market power of the taxpayer, his willingness to use it, and the responsiveness of factor owners and consumers to tax-induced price changes. Since there is little in the way of empirical analyses on the shifting of the taxes under consideration, the procedure characteristic of most incidence studies is followed and assumptions derived from abstract theory rather than from empirical observation are employed.

Taxes on Households

No shifting of the personal income tax, as is typical in incidence studies, is assumed in this study. Allowance was made for tax exporting, i.e., transfer of part of the burden to nonresidents. Some Iowa income tax is paid by nonresidents who earn income in the state, but most of the exporting is to the U. S. Treasury through personal deductions under the federal tax. If T_i is the amount of state income tax paid by Iowans in income group i, f_i is the typical marginal federal rate, and m_i is the proportion of taxpayers in the group who itemize, then the amount of tax exported to the U. S. Treasury is $T_i f_i m_i$ for group i. $T_i(1-f_i m_i)$ is the net incidence of the state income tax on taxpayers in i. The latter figure is reflected in the incidence percentages shown in Table 2.

Sales taxes on items purchased by households are allocated among income and occupation groups in accordance with data on the purchase of sales-taxed items as shown in federal budget studies [7, 8]. The portion exported to the U. S. Treasury through personal deductions is netted out. That portion of the Iowa sales tax paid by businesses but shifted to consumers (see below) is allocated in accordance with total consumer outlays.

The property tax on household personal property is virtually non-existent in Iowa. Property tax on dwellings is assumed to fall fully on the occupant, whether owner or renter. The assumption of forward shifting to renters seems reasonable in growing communities where elasticity of supply of housing is likely to be very high. In areas where rental units are in excess supply, forward shifting is less likely, but the difference in the income of renters and landlords may be small enough to make bias in these estimates unimportant. Again, the estimates are adjusted for export to the Treasury and to nonresidents.

Taxes on Business

Taxes on farm real estate are assumed to be unshifted, except for the export to non-residents and the Treasury. In the case of rented farm land, this in effect implies a zero supply elasticity. If the assumption is erroneous, the differential between tax incidence on owner-operators and tenants referred to above would be narrowed. Property taxes on farm personal property are assumed to be unshifted. Allocations of taxes on farm property to income groups are based on the results of an asset survey [5], except for the top two income brackets where thinness of the sample forced the authors to rely on farm record data collected by the Cooperative Extension Service at Iowa State University.

Iowa mercantile firms operate in markets characterized by a relatively homogeneous tax climate and market imperfections that make some forward shifting likely. It is assumed that half of the tax (after adjusting for export to the Treasury) is shifted forward with the remainder allocated to resident and non-resident owners.

Iowa industrial firms generally compete in a regional or national market against competitors who are not generally affected by Iowa taxes, making forward shifting more difficult. No forward shifting was assumed and after subtracting the Treasury export the tax to owners of the firms was assigned.

Taxes on public utilities are assumed to be shifted forward to customers (except for the Treasury share) via the regulatory process. They are allocated among business users on the basis of data obtained from an input-output table constructed for Iowa and among consumers on the basis of budget studies.

Measuring Income

The estimates of income on which the incidence estimates are based include adjusted gross income plus untaxed transfer payments plus unshifted business taxes. It represents an attempt to measure what the income of Iowa residents would be if some "angel" paid all Iowa state and local taxes due in 1969. Of particular

note is the fact that for farm owner-operators income includes unshifted farm property and sales taxes. This makes the tax burden of farmers appear to be lower than if income net of taxes had been used in calculating the various percentages.

What Taxpayers Think

Although the shifting assumptions used in this study are not based on taxpayer attitudes, results [6] from a 1965 questionnaire survey involving about 900 Iowa property owners may be of some relevance. The type of political behavior hypothesized is likely to reflect what taxpayers think they are paying for public services.

Of particular interest is the finding that 54 percent of the owners of mercantile property feel that they could shift a tax increase onto tenants, compared to 22.8 percent for residential property and 9.6 percent for agricultural land [6, p. 39]. Owners of businesses were asked how much of a 20 percent increase in property tax they could recover by raising prices. Fewer than 5 percent of the farmers said they could recover any of the increase and only about 2 percent predicted full recovery. In contrast, nearly 70 percent of the merchants said they could recover part or all of the increase [6, p. 43]. No estimates were obtained for industrial firms or utilities. These results appear to provide some support for the shifting assumptions described above.

References

[1] BLACK, DUNCAN, *The Theory of Committees and Elections*, Cambridge, Cambridge University Press, 1958.

[2] BOWEN, HOWARD R., "The Interpretation of Voting in the Allocation of Economic Resources," *Quart. J. Econ.* 58:27–48, Nov. 1943.

[3] DAVIES, DAVID G., "Progressiveness of a Sales Tax in Relation to Various Income Bases," *Am. Econ. Rev.* 50: 987–995, Dec. 1960.

[4] FRYMAN, RICHARD F., "Sales Taxation of Producers' Goods in Illinois," *Nat. Tax J.* 22:273–281, June 1969.

[5] MIKESELL, JAMES JAY, "The Structure and Distribution of Iowa Non-Corporate Real Property Assessments," unpublished M.S. thesis, Iowa State University, 1967.

[6] RUEBLING, CHARLOTTE EMMA, "The Shifting of Property Taxes in Iowa," unpublished M.S. thesis, Iowa State University, 1968.

[7] U. S. Department of Agriculture, *Consumer Expenditure and Income: Rural Farm Population, North Central Region, 1961*, Washington, 1965.

[8] U. S. Department of Labor, Bureau of Labor Statistics, *Consumer Expenditures and Income: Urban Places in North Central Region, 1960–61*, Washington, 1965.

Changing Federal Income Tax Rates and Optimum Farm Size*

Hoy F. Carman

Substantial reductions in income tax rates occurring over the last decade increase optimum farm size and thus contribute to the current movement toward fewer and larger farm units in the United States.

In research published in 1962, Dean and Carter [2] analyzed the impact of progressive income taxes on economies of scale and farm size for large-scale farms such as found in California. Their theoretical framework and empirical application demonstrated that if some of the costs included in cost curves are not tax deductible (such as opportunity cost interest), inclusion of the income tax as a cost will reduce the optimum level of output. The advantage of expansion through the use of borrowed capital was also demonstrated. Decreases in average effective federal income tax rates occurring since their analysis have implications for the long-run structure of agriculture.

Tax Rate Changes

Federal income tax rates were substantially reduced during 1964–65. The maximum marginal tax rate of 91 percent of income for amounts over $400,000 was reduced to a maximum of 70 percent for amounts over $200,000.[1] This reduced average income tax rates for all taxpayers with the amount of reduction increasing with increases in taxable income.

The Tax Reform Act of 1969 increased personal exemptions and standard deductions. The value of increases in personal exemptions increases with income, while the increase in standard deductions primarily benefits low income taxpayers who choose not to itemize deductions. A provision benefiting some high-income individuals is the maximum tax rate of 50 percent on earned income.[2] Earned income includes wages, salaries, professional fees, or compensation for personal services. However, if the taxpayer is engaged in a trade or business such as farming in which both capital and personal services are income-producing factors, earned income is a reasonable allowance for personal services rendered but not in excess of 30 percent of the net profits [5, pp. viii–ix]. Thus, for the present analysis, this provision only influences tax calculations for taxable incomes over $173,000. Other provisions increase capital gains tax rates and establish minimum tax rates on certain tax preference items. These provisions are not considered here because all budgeted income is ordinary income.

An Example

The empirical cost function for large field-crop and vegetable crop farms in the Imperial Valley, California, developed by Dean and Carter is used to demonstrate the changing impact of federal income taxes on optimum farm size.[3] The total cost curves in the upper portion of Figure 1 include income taxes and an opportunity cost for capital at a 3.5 percent tax-free bond rate.[4] Net returns to management for an owner-operator with 100 percent equity is the difference between total revenue and total costs. Net returns to management for 1962 and 1972 income tax rates are shown by the solid lines in the lower portion of Figure 1. This analysis differs from the original in that state income taxes are not included in the calculation. Their inclusion would not change the conclusions.

Given 1962 tax rates, net returns to management are maximized by expanding farm size to the 1250–1750 acre range and then investing any excess funds in tax-free bonds rather than in farming (Fig. 1). Decreases in tax rates, fully effective in 1972, change this conclusion.[5] Within the range of farm sizes considered, the

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[1] All references to tax rates and tax computations assume a married taxpayer with two children. For a description of the tax rate changes see [6].

[2] The maximum tax rate on earned income is 60 percent in 1971 and 50 percent in 1972. For a discussion of earned income and tax calculations see [3, pp. 48–50].

Hoy F. Carman *is associate professor of agricultural economics and associate agricultural economist in the Experiment Station and on the Giannini Foundation, University of California, Davis.*

[3] The assumptions and specifications for the original analysis are utilized for this analysis. See [1, pp. 22–25; 2, p. 759].

[4] The total cost curves correspond to C_6' in the original study [2, p. 760].

[5] The 1972 rates do not include any of the proposals currently being considered by Congress.

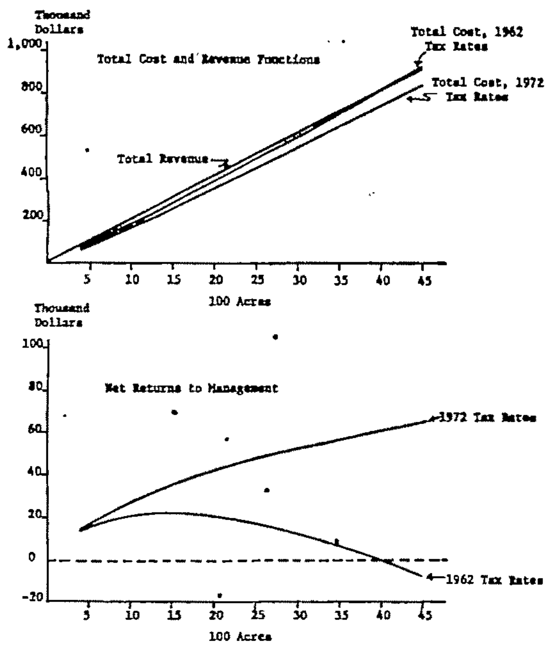

Figure 1. Empirical cost and revenue functions and net returns to management for federal income tax rates existing in 1962 and 1972

operator maximizes management returns by expanding farm size to the maximum (4,500 acres).

Dean and Carter found that " . . . expansion through borrowed capital promises relatively constant average costs, increasing management returns, and therefore an attractive method of expansion" [2, p. 762]. Net returns to management for an owner-operator with 50 percent equity for 1962 income tax rates are maximized for a farm size of 2,500–3,500 acres, approximately double the optimum size for an owner-operator with 100 percent equity. Under 1972 tax rates, the owner-operator with 50 percent equity would maximize management returns by expanding farm size to the maximum size considered (4,500 acres).

Summary and Implications

This analysis considers only the effect of changing federal income tax rates; it does not represent actual costs and returns existing today. Changes in prices of inputs and products combined with new technology have undoubtedly shifted the basic cost and revenue functions over time.[6] Thus, the acreage figures for optimum farm size are useful only for comparison purposes. But the conclusions with regard to changes in tax rates hold. Progressive income taxes continue to place restraints on farm size but not to the extent they once did. It is clear that tax rate changes occurring over the last decade favor increased scale of farms and expansion through borrowed capital. Some provisions, such as the maximum tax on earned income, benefit only very high income farmers. The immediate impact of tax rate decreases is higher after tax income but, over time, these same decreases will support the current movement toward fewer and larger farm units.

[6] Goetz and Weber [4, p. 51] found, for example, that because of inflation many taxpayers face higher real tax rates in 1970 than they did in 1954, despite the decreases in the statutory tax rate structure occurring during 1964–65 and 1969.

References

[1] CARTER, H. O., AND G. W. DEAN, *Cost-Size Relationships for Cash Crop Farms, Imperial Valley, California*, Giannini Foundation Res. Rep. No. 253, May 1962.

[2] DEAN, GERALD W., AND HAROLD O. CARTER, "Some Effects of Income Taxes on Large-Scale Agriculture," *J. Farm Econ.* 44:754–768, Aug. 1962.

[3] *Explanations of the Tax Reform Act of 1969 (P.L. 91–172)*, Publication 5172, New York, Commerce Clearing House, Inc., 1969.

[4] GOETZ, CHARLES J., AND WARREN E. WEBER, "Intertemporal Changes in Real Federal Income Tax Rates, 1954–70," *Natl. Tax J.* 24:51–63, March 1971.

[5] O'BYRNE, JOHN C., *Farm Income Tax Manual*, 4th ed., including *1970 Pocket Supplement*, Indianapolis, The Allen Smith Company, 1970.

[6] Public Law 88–272, 88th Cong., H.R. 8363, Feb. 26, 1964.

Predicting the Effects of High-Lysine Corn on the Hog Economy*

A. GENE NELSON AND TIMOTHY M. HAMMONDS

Estimation of a supply and demand model of the hog economy is presented for analyzing the possible effects of high-lysine corn. Changes in hog marketings and prices are predicted as a function of the feed cost savings resulting from the successful introduction of high-lysine corn.

THIS NOTE is directed to the problem of assessing the potential effects of high-lysine corn on the nation's hog economy. A supply and demand model was estimated for the analysis of this problem. The supply response function explains the number of hogs marketed, considering that (1) production decisions are based on future price expectations formulated in an uncertain environment and that (2) there are lags in adjustment after these decisions are made.

Supply and Demand Model

The supply and demand model is based on Nerlove's generalization [8, p. 219] of Ezekiel's cobweb theorem which is applicable "(1) where production is completely determined by the producers' response to price, under conditions of pure competition (where the producer bases plans for future production on the assumption present prices will continue, and that his own production plans will not affect the market); (2) where the time needed for production requires at least one full period before production can be changed, once the plans are made; and (3) where the price is set by the supply available" [4, p. 272].

Nerlove's generalization involves the condition that "the producer bases his plans for future production on the assumption that present prices will continue." Nerlove argues that producers will respond to their expectations regarding the "normal" price, rather than the present price. An advantage of this formulation is the increased possibility for stability in the model, i.e., that prices will converge over time [8, pp. 56–57].

It appears that the live hog market approximates the conditions of Nerlove's generalized case. The period of time required to produce a hog, from breeding to slaughter, is 9 to 12 months. Variation in the weights of hogs marketed in response to short-run price changes may occur, but the number of hogs marketed in a year is essentially predetermined. Thus, consistent with Nerlove's argument, hog production plans are assumed to be based upon the expected "normal" price, and current prices influence the formulation of these expectations.

An important characteristic of the cobweb model, set forth by Buchanan [1, p. 68], is that the supply curve must be ". . . completely reversible throughout its whole length with respect to each (time) period." This property of reversibility, i.e., complete ease of adjustment to any anticipated price in the interval between production periods, means that this supply curve possesses ". . . some of the characteristics of long-period competitive supply curves" [1, p. 69].

The supply relationship hypothesized in this study expresses the "long-run" equilibrium number of hogs marketed as a function of the "normal" price producers expect to receive for hogs, the expected "normal" feed prices, and the expected "normal" price of beef cattle. The supply function for hogs is

$$(1) \quad Q_t^* = b_0 + b_1P_t^* + b_2F_t^* + b_3C_t^* + u_t,$$

where the long-run output of hogs, Q_t^*, depends on P_t^*, F_t^*, and C_t^*, the expected "normal" prices, respectively, of hogs, feed, and cattle.

The quantity, Q_t^*, is that which would be supplied in the long run if current prices were to persist indefinitely. Due to lags in adjustment resulting from psychological, technological, and institutional rigidities, there exists a difference between Q_t^*, the long-run equilibrium quantity supplied, and Q_t, the observable short-run quantity supplied. The pattern of adjustment of Q_t to Q_t^* is assumed to be of the form prescribed in the following equation:

$$(2) \qquad Q_t - Q_{t-1} = \delta[Q_t^* - Q_{t-1}],$$

where δ is a constant called the coefficient of adjustment. Equation (2) assumes that the lag is distributed over time such that in each period

* The authors acknowledge the helpful comments of James E. Martin, Virginia Polytechnic Institute.

A. GENE NELSON *and* TIMOTHY M. HAMMONDS *are assistant professors of agricultural economics at Oregon State University, Corvallis.*

the actual quantity marketed is adjusted in constant proportion to the difference between the quantity supplied in the long run and the actual quantity marketed.

Enthoven and Arrow [3, p. 289] state that any change in the price expectation may be divided into two components: (1) autonomous and (2) induced. Autonomous changes result from causal factors, while induced changes result from changes in current prices. Because the typical producer is not generally aware of the specific reasons for a particular price change, he must use past prices as his guide in formulating expectations. Also, any change in the current price can be thought of as divided into two components: (1) permanent and (2) transitory [7, p. 21]. The permanent component affects all expected future prices, while the transitory component affects only some, or maybe none, of them.

Nerlove's concept of expectations is based on Enthoven and Arrow's work. He specifies the average level about which future prices are expected to fluctuate as the expected "normal" price [7, p. 21]. Expectations about this normal price are single-valued. As defined, changes in the expected normal price are ***induced*** only by the ***permanent*** components of changes in current price. The ***transitory*** components of changes in current price affect only the deviations of expected future prices about the expected normal price.

Applying Nerlove's formulation, one has

$$P_t^* - P^*_{t-1} = \beta[P_{t-1} - P^*_{t-1}], \tag{3}$$

$$F_t^* - F^*_{t-1} = \beta[F_{t-1} - F^*_{t-1}], \text{ and} \tag{4}$$

$$C_t^* - C^*_{t-1} = \beta[C_{t-1} - C^*_{t-1}]. \tag{5}$$

The β is a constant called the coefficient of expectation, which is simply the proportion of the change in current price that is regarded as permanent. The proportion regarded as transitory is $1-\beta$. The simplifying assumption is made that the coefficient of expectation is the same for P, F, and C. This assumption allows a less complex estimational procedure.

The supply function cannot be estimated directly because the variables are not observable. However, by solving the system consisting of equations (1) through (5), the following equation is derived:

$$\begin{aligned} Q_t = {} & b_0\beta\delta + b_1\beta\delta P_{t-1} + b_2\beta\delta F_{t-1} + b_3\beta\delta C_{t-1} \\ & + (1 - \beta + 1 - \delta)Q_{t-1} \\ & + (\beta - 1)(1 - \delta)Q_{t-2} + v_t. \end{aligned} \tag{6}$$

An important characteristic of equation (6) is that β and δ enter the expression symmetrically. Thus, it is impossible with the ordinary least squares method of estimation to distinguish the effects of each or to obtain unique estimates of either. However, unique estimates of the b_i's can be obtained from the estimation of the equation,

$$\begin{aligned} \hat{Q}_t = {} & \hat{\pi}_0 + \hat{\pi}_1 P_{t-1} + \hat{\pi}_2 F_{t-1} + \hat{\pi}_3 C_{t-1} \\ & + \hat{\pi}_4 Q_{t-1} + \hat{\pi}_5 Q_{t-2}. \end{aligned} \tag{7}$$

From this regression equation estimates of the b_i's, the long-run supply parameters, can be determined as follows [7, p. 69]:

$$\hat{b}_i = \hat{\pi}_i/(1 - \hat{\pi}_4 - \hat{\pi}_5). \tag{8}$$

The demand relationship hypothesized expresses the current hog price, P_t, as a function of the number of hogs marketed per capita, beef and veal consumption per capita, poultry consumption per capita, and disposable personal income per capita:

$$\begin{aligned} P_t = {} & a_0 + a_1 Q_t/N_t + a_2 S_t + a_3 R_t \\ & + a_4 I_t + w_t. \end{aligned} \tag{9}$$

Within the time period of the observations, i.e., one year, the number of hogs is essentially predetermined. Therefore, the price of hogs becomes the dependent variable. It is assumed that within a year any adjustments of price to changes in the demand variables are completed. Thus, the short-run and long-run demand parameters are taken as being equivalent.

Statistical Results

The ordinary least squares (OLS) regression equation for the demand function is

$$\begin{aligned} \hat{P}_t = {} & \underset{(5.9)}{70.70} - \underset{(4.8)}{1.02}Q_t/N_t - \underset{(4.2)}{0.41}S_t \\ & - \underset{(2.3)}{0.56}R_t + \underset{(3.2)}{0.027}I_t \end{aligned} \tag{10}$$

$R^2 = 0.63 \qquad (\ ) = t\text{-values.}$

The OLS regression equation for the supply function is

$$\begin{aligned} \hat{Q}_t = {} & \underset{(3.8)}{91.84} + \underset{(2.0)}{0.84}P_{t-1} - \underset{(4.9)}{0.44}F_{t-1} \\ & + \underset{(0.9)}{0.27}C_{t-1} + \underset{(2.5)}{0.64}Q_{t-1} - \underset{(3.0)}{0.49}Q_{t-2} \end{aligned} \tag{11}$$

$R^2 = 0.81 \qquad (\ ) = t\text{-values.}$

Employing Equation (8), the estimated long-run supply equation can be derived from equation (11):

$$\hat{Q}_t^* = 108.80 + 1.00P_t^* - 0.52F_t^* + 0.32C_t^*. \tag{12}$$

The variables are defined as follows:[1]

- P is the price of hogs (dollars per cwt.) deflated by WPI;
- Q is the number of hogs marketed (millions);
- N is the U.S. population (hundred-millions);
- S is the beef and veal consumption per capita (lbs.);
- R is the poultry consumption per capita (lbs.);
- I is the disposable personal income per capita (dollars) deflated by CPI;
- F is the index of feed costs (1957–59 = 100) deflated by WPI; and
- C is the price of beef cattle (dollars per cwt.) deflated by WPI.

All of the coefficients have satisfactory t-values and signs consistent with *a priori* expectations, with the exception of the cattle price coefficient in the supply equation. Since this is the price of a substitute product, its sign should be negative. Instead, its sign is positive but insignificant in equation (11). The decision to leave this variable in the model was based on two reasons. First, the purpose of this model is to estimate the impact of high-lysine corn on hog marketings and price levels. As such, the individual coefficient of cattle prices is not of critical importance, and its presence does contribute marginally to the predictive power of the model. Second, and more fundamentally, the impact of substitutes is important in the economic theory of supply. The fact that it is insignificant with this data set does not necessarily justify its exclusion.

Serial correlation in the residuals of an autoregressive model may lead to inconsistent parameter estimates [5, p. 36]. This is a much more serious difficulty than the presence of serially correlated residuals in a more standard regression model leading only to inefficient estimates.[2] Since it is well known that the Durbin-Watson statistic is inappropriate for a model of this form, an alternative method was used to investigate the nature of the error terms. The maximum likelihood estimate of the coefficient of serial correlation was obtained with an OLS regression and tested as suggested in a recent article by Durbin [2, p. 420].

For the demand equation,

$$\begin{aligned} \hat{u}_t = {} & \underset{(1.1)}{0.30\hat{u}_{t-1}} + \underset{(0.3)}{0.03Q_t/N_t} + \underset{(0.04)}{0.003S_t} \\ & + \underset{(0.5)}{0.14R_t} - \underset{(0.4)}{0.003I_t}. \end{aligned} \tag{13}$$

( ) = t-values

For the supply equation,

$$\begin{aligned} \hat{v}_t = {} & -\underset{(0.9)}{0.32\hat{v}_{t-1}} - \underset{(0.1)}{0.05P_{t-1}} + \underset{(0.01)}{0.001F_{t-1}} \\ & - \underset{(0.4)}{0.13C_{t-1}} + \underset{(0.6)}{0.13\hat{Q}_{t-1}} - \underset{(0.4)}{0.08Q_{t-2}}. \end{aligned} \tag{14}$$

( ) = t-values

In equations (13) and (14) the coefficients of the lagged residuals are insignificant. It may be concluded, therefore, that no serial correlation exists among the residuals and that the parameter estimates are consistent.

Impact of High-Lysine Corn

The supply and demand model was used to analyze the possible effects of high-lysine corn on the hog economy. Assuming a stable equilibrium in the live hog market, the long-run price and quantity will tend to converge. By adjusting the cost of feed to account for the saving due to high-lysine corn, its effects on this equilibrium can be estimated.

Compared to ordinary corn, high-lysine corn contains higher levels of the amino acids, lysine and tryptophane. Experimental feeding trials indicate that hogs fed high-lysine corn require less protein supplement. A result is the potential for significant savings in hog feed costs.

The magnitude of this feed cost saving will depend on at least three main factors: (1) The yield per acre of high-lysine, compared to regular corn, will affect its cost per bushel. (2) The nutrient composition of high-lysine corn will affect its substitutability for other feedstuffs in swine rations. (3) The supply curve for hog protein supplements, particularly soybean oil meal, will affect the price of these supplements if high-lysine corn shifts the demand.

[1] The time series data from 1949 through 1970 were used to measure the variables. For data sources and adjustments, contact the authors.

[2] See Griliches [5] for a discussion of the properties of coefficient estimates under various assumptions about the form of the residual correlation.

The estimated changes in the number and price of hogs marketed after the hog industry has had time to adjust to the feeding of high-lysine corn were calculated from the supply and demand model. The calculations are based on assumed decreases in deflated feed costs of 2 to 10 percent, as compared to the mean for the 1961–70 decade.[3] Also, the U. S. population was set at 2.1 million and the Wholesale Price Index (1957–59 = 100) at 125. The expansion in hog marketings and resultant price decline are indicated in Table 1 as a function of feed cost savings which could result from the successful innovation of high-lysine corn.

[3] In previous research a linear programming feed formulation model, solved for various situations, indicated feed cost savings within the range of these assumptions. See Nelson [6].

Table 1. Estimated change in annual hog marketings and price levels under various assumed feed cost savings due to high-lysine corn

Decrease in feed costs[a]	Change in	
	Hog marketings[b]	Hog prices[b]
(percent)	(1,000's)	($ per cwt.)
2	+ 688	−0.42
4	+1,376	−0.83
6	+2,064	−1.25
8	+2,752	−1.67
10	+3,441	−2.09

[a] This percentage decrease is relative to the 1961–70 average deflated feed cost.
[b] These estimates are based on 2.1 million population and 125 *WPI*.

References

[1] BUCHANAN, N. S., "A Reconsideration of the Cobweb Theorem," *J. Polit. Econ.* 47:67–81, 1939.

[2] DURBIN, J., "Testing for Serial Correlation in Least-Squares Regression When Some of the Regressors are Lagged Dependent Variables," *Econometrica* 38:410–421, May 1970.

[3] ENTHOVEN, ALAIN C., AND KENNETH J. ARROW, "A Theorem on Expectations and the Stability of Equilibrium," *Econometrica* 24:288–293, July 1956.

[4] EZEKIEL, M., "The Cobweb Theorem," *Quart. J. Econ.* 52:255–280, 1938.

[5] GRILICHES, ZVI, "Distributed Lags: A Survey," *Econometrica* 35: 16–49, Jan. 1967.

[6] NELSON, A. GENE, "The Potential Effects of High-Lysine Corn on the Hog Economy," *Economic and Marketing Information for Indiana Farmers*, Purdue University, May 31, 1968.

[7] NERLOVE, MARC, *Distributed Lags and Demand Analysis for Agricultural and Other Commodities*, USDA Agr. Handbook No. 141, 1958.

[8] ———, *The Dynamics of Supply: Estimation of Farmers' Response to Price*, Baltimore, The Johns Hopkins Press, 1958.

Price Alignment and Movements of Class I Milk Between Markets*

Leo V. Blakley and Donald W. Kloth

Incentives to transfer milk from one surplus market to another exist under current price alignment. Lower location differentials reduce these incentives. Milk shipments not needed for fluid consumption increase total costs with net benefits accruing primarily to the transportation industry and to some producer groups at the expense of others.

Class I milk prices in the 48 United States have tended to be lowest in the upper North Central region and to increase as distance from this area becomes greater. In many of the markets, the prices are consistent with those generated from a basing-point pricing system using Eau Claire, Wisconsin, as the base point. The prices, therefore, reflect an implicit transfer cost schedule even though production from nearby areas serving local markets has been the typical pattern in the industry with only an occasional need for intermarket movement of milk.

The implicit transfer costs for Class I milk in the federal order pricing structure have been estimated by Babb [1], Lasley [5], Freeman [2], and others. Based on Babb's study, the implicit transfer costs were 16.9 cents per hundredweight per 100 miles from Eau Claire for Class I prices and 14.9 cents for blend prices in 1963. Some decline over time was evident in the series and the implicit costs appeared to approximate 15 cents per unit-mile for Class I milk by the mid-1960's.

Actual transfer costs appeared to be about the same or slightly higher than the implicit transfer costs prior to the mid-1960's. However, actual transfer costs were poised for a large relative decline in the last half of the decade. Improvements in the transportation system, both in roads and equipment, had resulted in much lower transportation costs and the potential for longer distance shipment of milk. Moreover, the quality of raw milk was improving and becoming more uniform throughout the entire geographical area. As a consequence of these and other developments, both the geographical structure of Class I prices and the delineation of specific market areas were under great pressures to change.

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Leo V. Blakley *is professor of agricultural economics at Oklahoma State University and* Donald W. Kloth *is economist, Corporate Planning Division, Anheuser-Busch, Inc.*

The application of competitive market principles to determine intermarket price relationships for milk markets which are self-sufficient in production is unsatisfactory, though Manchester [7, p. 41] states that there seems to be no alternative. The principles, however, might be used to establish ranges of prices in outlying markets[1] within which actual market prices must lie. The actual price relationships among markets would be somewhat arbitrary and subject to manipulation toward either a maximum or minimum producer price depending upon the strength of the producer groups in the various markets.

In this study, the transport-separable model and the input data reported in Kloth and Blakley [3, 4] are used to analyze the impacts of price alignment using alternative transfer cost allowance levels in a basing-point pricing system. There are 105 demand areas and 92 supply areas aggregated into nine regions of the U. S. and further aggregated into five major regions as follows: Northeast, Southern, North Central, West South Central, and West. A market structure involving market share restrictions for individual firms, similar to Model B in that study, is specified. That is, two or more firms must be serving each of the major markets in the optimum organization of the industry. Linear assembly and distribution cost functions are assumed but processing costs are estimated from a nonlinear function which reflects economies of size in processing.[2]

[1] An outlying market is a market located at some distance from a basing-point location.

[2] The cost function to be minimized is

$$TC = \sum_{j=1}^{n} \sum_{i=1}^{m} C_{ij}X_{ij} + \sum_{i=1}^{m} f(X_i) + \sum_{k=1}^{p} \sum_{i=1}^{m} T_{ki}X_{ki}$$

where

TC = total costs for the assembly, processing, and distribution of milk for fluid consumption;

X_{ij} = quantity of processed milk shipped from processing area i to demand area j;

C_{ij} = per unit distribution cost of shipping processed milk from processing area i to demand area j and is equal to $6.5134+0.16025\ M_{ij}$;

The market setting is 1965. The base price of the resource, Class I milk, is assumed to be \$3.60 per 100 pounds at the location of Eau Claire, Wisconsin. Prices in the various markets are determined from this base price plus a transfer cost allowance related to distance from Eau Claire. Three models, each using a different transfer cost level, are specified. The first, Model X, has Class I prices based on the base price plus a transfer cost allowance of \$0.15 per hundredweight per 100 miles from Eau Claire. The second, Model Y, has Class I prices based on a lower transfer cost allowance of \$0.09 per hundredweight per 100 miles from Eau Claire. The third, Model Z, assumes that processors in all markets pay a common base price (same in all markets). In all models, processors pay the price in the exporting market plus transfer costs from the exporting to the importing market for any milk moved between markets.

Market Areas for Bulk Milk

The movements of milk between markets in the various models are summarized in terms of both intermarket and interregional transfers.[3] Intermarket transfers are largest and include movements of milk between adjacent as well as distant markets. Interregional transfers on the other hand emphasize the longer distance movements of milk, though some transfers between adjacent markets located in different regions are included.

The 15 cents per unit-mile transfer cost allowance level in the pricing system is higher in Model X than actual transfer costs, and milk in many markets distant from the base point is displaced by production from areas closer to and in the direction of the base point. The directional flows are illustrated in Section A of Figure 1. Intermarket transfers of bulk Class I milk total 2.0 billion pounds per month or 42.7 percent of total utilization. Interregional transfers at 1.1 billion pounds per month represent slightly over one-half the total intermarket transfers (Table 1).

Exports to the Pacific region under Model X are made from the Mountain, West South Central, West North Central, and East North Central regions, all located in the direction of the basing-point location. Most of the exports are from Minnesota and Wisconsin near the base point.

The Mountain region, in turn, receives almost as much milk from areas in the direction of the base point as it transfers to the Pacific region. A similar pattern exists for areas to the south and east of the base point. The basing point location and the 15-cent transfer cost allowance level result in a competitive advantage for milk produced in the North Central region.

Both intermarket transfers and interregional transfers of bulk milk decline when the transfer cost allowance is lowered to 9.0 cents per unit-mile. Further declines occur when the transfer cost allowance is eliminated as in Model Z (a single price system). The intermarket flows for Model Z are shown in Section B of Figure 1. Of the 1.2 billion pounds being transferred between markets, less than 10 percent is transferred between regions. No region is involved with either large exports or large imports in Model Z.

Market Areas for Packaged Milk

The impacts of a basing-point pricing system on manufacturing firms have been discussed by Machlup [6] and others. There is a competitive advantage for processing firms located at or in the direction of the basing point. Processing firms would never be at a raw material price disadvantage when located at the basing point. In contrast, a firm in a local market in an outlying area would encounter freight absorption if it attempted to compete in a market closer to the basing point. Significant economies of size in processing would magnify the advantage of processors at basing-point locations.

Large interregional transfers of packaged milk did not occur in these models, though large transfers would exist if market share restrictions on individual firms were relaxed [3]. Intermarket transfers in million pounds per month were 698.0 for Model X, 710.5 for Model Y, and 577.8 for Model Z. Interregional transfers in contrast were only 265.9, 282.7, and 93.6

M_{ij} = one-way mileage from processing area i to demand area j;

$f(X_i)$ = nonlinear function expressing the total cost of processing quantity X_i in processing area i (the basic processing cost function in cents per quart is the exponential $11.763X_{gi}^{-0.11607}$ where X_{gi} is quarts of milk processed per day by plant g in area i;

T_{ki} = per unit assembly cost of shipping raw milk from supply area k to processing area i and is equal to $11.405+0.1126M_{ki}$;

M_{ki} = one-way mileage from production area k to processing area i;

X_{ki} = quantity of raw milk shipped from supply area k to processing area i.

[3] The outlines of the regions are shown as heavy lines in Figures 1 and 2.

Table 1. Interregional transfers of bulk Class I milk in three alternative models, by regions of the U. S.

Exporting Region	Importing Region	Quantity Transferred		
		Model		
		X	Y	Z
		(million pounds per month)		
Western				
Mountain	Pacific	93.2	46.6	11.8
	West South Central	0	0	2.4
West South Central	East South Central	6.2	6.3	7.8
	Pacific	12.2	0	0
Southern				
South Atlantic	East South Central	0	0	17.2
	Mid-Atlantic	0	30.2	0
East South Central	West South Central	0	8.8	8.8
	South Atlantic	0	0	15.1
North Central				
West North Central	Pacific	249.3	18.8	0
	Mountain	75.8	16.8	0
	West South Central	26.8	5.8	0
	East North Central	4.2	0.7	14.0
	East South Central	4.1	0	0
East North Central	Pacific	35.7	0	0
	West North Central	29.0	0	0.7
	East South Central	71.3	27.6	35.0
	South Atlantic	249.6	56.1	0
	Mid-Atlantic	56.0	64.1	0
	New England	57.1	0	0
Northeast				
Mid-Atlantic	New England	164.9	0	0
Total regional exports		1,135.4	281.8	112.8

million pounds per month, respectively (Table 2). The increases reported for Model Y as compared with Model X resulted from increased shipments from New York in the Mid-Atlantic region. With lower transfer costs, the economies of size offset the disadvantage of shipment laterally from a straight line connecting the market to the base point.

Directional movements and areas of competitive advantage for packaged processed milk were about the same as for raw milk at the 15-cent transfer cost allowance level (Section A of Figure 2). Almost all the flows in Model X were in the direction away from the base point. At the zero transfer cost allowance level (single price system) of Model Z, on the other hand, more areas were involved in exporting packaged milk and some of the exports were in the direction of the base point (Section B of Figure 2). For example, some exports to the Mountain region were made from the Pacific region, and the Mountain region exported milk to the West South Central region.

Organizational Costs

The smaller the transfer cost allowance levels, the lower were total organizational costs for the industry.[4] The total of the included costs were $71.8 million for Model X, $62.1 million for Model Y, and $60.3 million for Model Z.

Most of the differences in total costs reflected differences in intermarket assembly costs under varying transfer cost allowance rates. Assembly costs were $15.1, $5.6, and $3.6 million, respectively, for Models X, Y, and Z. Processing costs

[4] Total organizational cost was defined to include (a) assembly costs which involve transporting milk from the major locations in supply areas to plants actually processing milk in the demand areas, (b) total processing costs which are incurred by the firms processing milk in the demand areas, and (c) distribution costs which involve transporting milk from the processing plants to market centers in the demand areas which actually consume the milk. The total cost therefore excludes farm assembly costs (transfer from farm to major supply point) and final distribution costs (transfer from major market center in each demand area to homes or retail stores in that area).

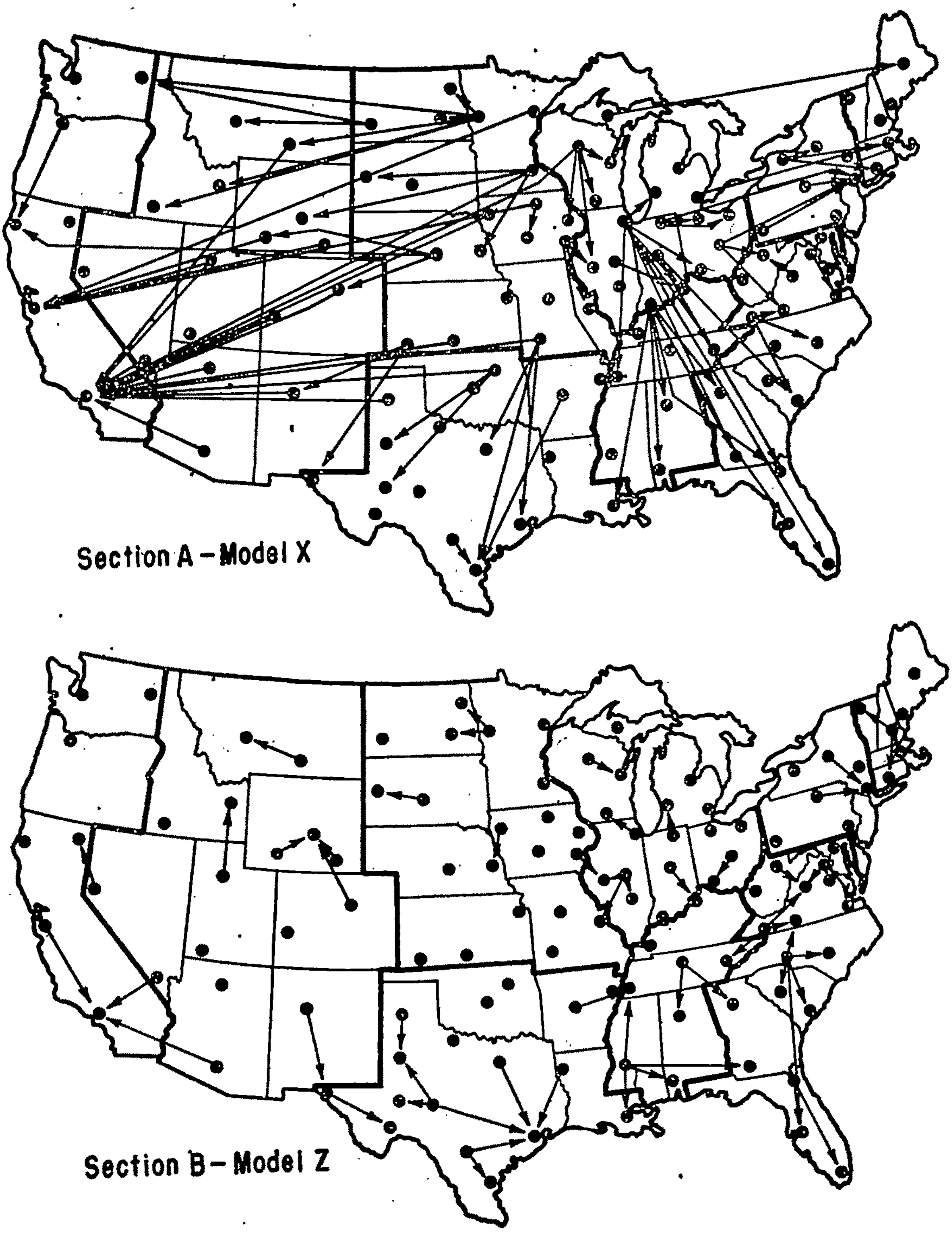

Figure 1. Optimum flow patterns of raw milk from production areas to processing facilities, models X and Z

Table 2. Interregional transfers of processed and packaged Class I milk in three alternative models, by regions of the U. S.

Exporting Region	Importing Region	Quantity Transferred		
		Model		
		X	Y	Z
		(million pounds per month)		
Western				
Mountain	Pacific	4.5	4.5	0
	West South Central	0	0	0.9
Pacific	Mountain	0	0	2.0
West South Central	(none)	0	0	0
Southern				
South Atlantic	(none)	0	0	0.
East South Central	South Atlantic	5.7	0	2.2
	East North Central	0	0	1.4
North Central				
West North Central	Mountain	0.3	0.5	0
	West South Central	20.4	20.4	16.6
	East North Central	23.3	17.9	16.6
	East South Central	12.6	12.6	0
East North Central	West North Central	3.3	3.3	3.3
	East South Central	3.8	3.8	3.8
	South Atlantic	32.8	30.9	2.7
	Mid-Atlantic	56.9	51.5	7.8
Northeastern				
Mid-Atlantic	South Atlantic	30.8	30.8	14.2
	New England	71.5	106.5	22.1
New England	(none)	0	0	0
Total regional exports		265.9	282.7	93.6

and distribution costs were not sensitive to varying transfer rates. The ratio of processing costs to distribution costs did not vary in a consistent way with transfer cost allowance rates. A few more firms operating at a slightly lower average size were indicated under the single price system (249 firms in Model Z) than under the base price plus 15 cents per unit-mile transfer cost allowance level (239 firms in Model X). The major difference was the larger number of plants operating in the New England area under the single price system.

Impact on Producers

The analysis indicates that Grade A milk producers in most areas have a large vested interest in the transfer cost allowance level to be used in the basing-point pricing system for aligning federal order prices. A transfer cost allowance level of 15 cents per hundredweight per 100 miles in the pricing systems with estimated current transfer costs results in the use of practically all production in the North Central region for Class I purposes (Table 3). This use is at the expense of local production in markets located away from the basing-point location such as the West. The impact is greatest for markets in the New England and Pacific regions where more than three-fourths of local production remains unused. Markets in the South also have large quantities of unused production. The local milk would have to go into lower class uses. The final result of this utilization would be higher blend prices in major supply areas and lower blend prices in local areas. These results are consistent with Freeman's [2] conclusion that prices in the upper Midwest are comparatively low with large shipments indicated under equilibrium conditions.

Reducing the transfer cost allowance level from 15.0 to 9.0 cents per unit-mile drastically alters the percentages of production unused for

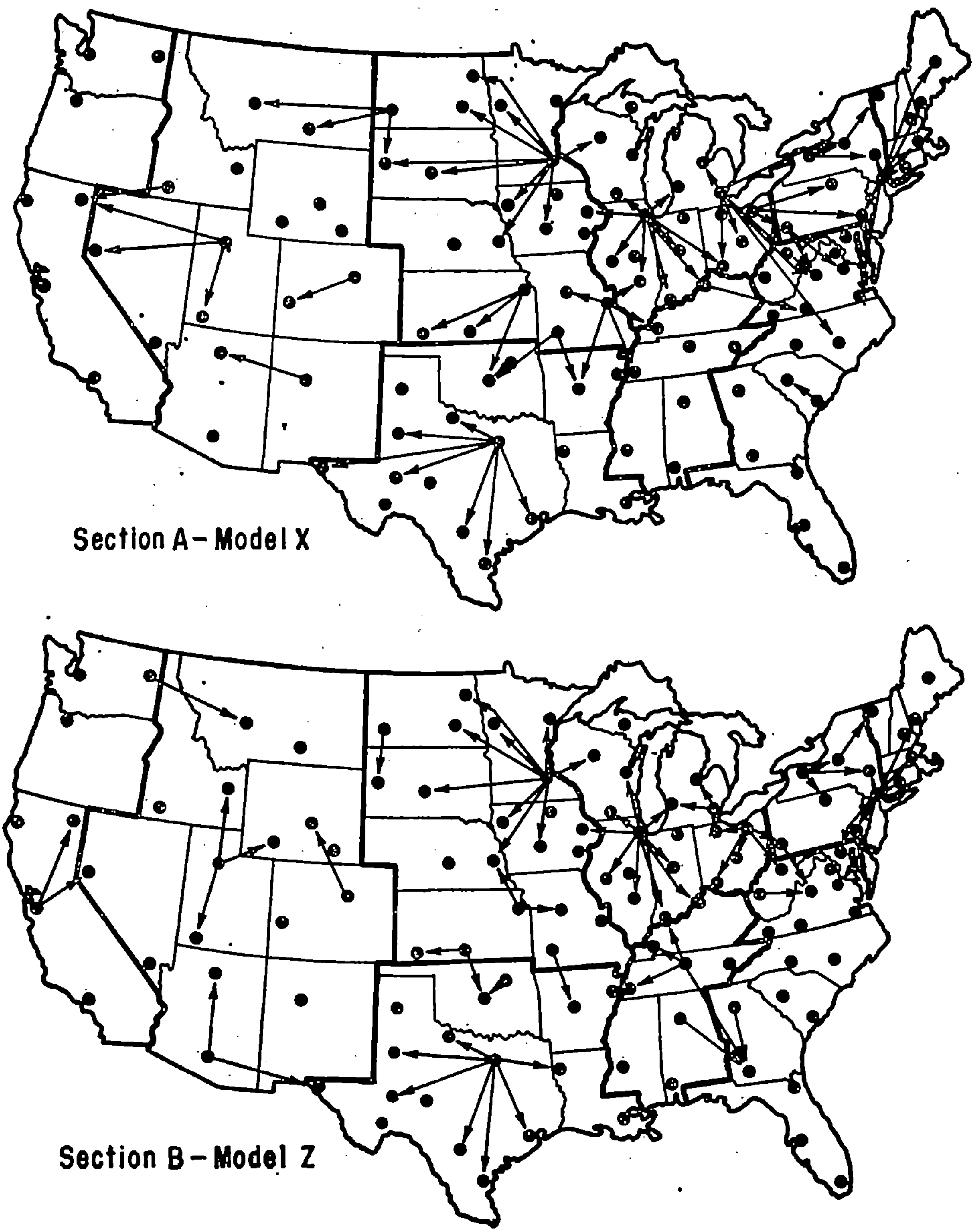

Figure 2. Optimum flow patterns of packaged milk from processing facilities to market areas, models X and Z

Table 3. Total production and percentage of production unused for Class I purposes in three alternative models, by regions of the U. S.

	Total Production	Unused Production		
		Model		
		X	Y	Z
	(Million Pounds per month)	(Percent of Total Production)		
Western	1,013.7	62.5	29.2	25.4
Pacific	786.5	76.6	35.1	27.4
Mountain	227.2	13.6	9.1	18.2
West South Central	417.9	13.8	12.6	9.8
Southern	811.1	40.4	15.1	1.7
South Atlantic	590.5	46.3	14.1	2.2
East South Central	220.6	24.5	17.5	0.5
North Central	2,405.7	0.3	24.1	35.7
West North Central	818.6	0	35.5	41.7
East North Central	1,587.1	0.4	18.2	32.6
Northeastern	1,860.7	43.2	41.9	35.4
Mid-Atlantic	1,490.5	29.2	40.1	37.6
New England	370.2	100.0	49.5	26.7
Total	6,509.1	28.1	28.1	28.1

Class I purposes. The percentage of unused production drops from 76.6 to 35.1 for the Pacific region and from 100.0 to 49.5 in the New England region. On the other hand, more (a total of about one-fourth) of the milk in the North Central region is unused. Outside the North Central region, only the Mid-Atlantic area has more unused production at the 9.0 cent transfer cost allowance level.

Elimination of intermarket price differences results in reduced incentives for intermarket transfers of milk. In Model Z, more local milk is used in markets in all outlying regions except in the Mountain. The percentages of milk unused are higher in the West North Central and East North Central regions, the regions at or near the original base point. The percentages of unused production are comparable with some of the reported regional averages computed for the Class I utilization percentages for federal order markets [8]. Though the market coverage in this study is greater than the federal order market data, the percentages are within three points of each other for the Mountain, East North Central, Mid-Atlantic, and New England areas. The percentages were lower than the federal order data for most of the other regions.

Conclusion

Current alignment of Class I prices on the basis of location differentials approximating 15 cents per hundredweight per 100 miles from a location such as Eau Claire, Wisconsin, creates incentives to transfer milk from one market to another even though both may be "surplus" markets. The movement of Class I milk between markets, when it is not needed for fluid consumption, increases total costs with benefits accruing primarily to the transportation industry. The distribution of benefits between producers in various production areas and processors and consumers in demand areas are also affected, but no evaluations of net benefits from trade-offs were attempted.

References

[1] BABB, E. M., *Intermarket Price Relationships 1961–1964*, Indiana Agr. Exp. Sta. Res. Prog. Rep. 197, July 1965.

[2] FREEMAN, ROBERT E., *Geographic Pattern of Fluid Milk Prices: A Computer Analysis*, USDA Market. Res. Rep. 818, April 1968.

[3] KLOTH, DONALD W., AND LEO V. BLAKLEY, "Optimum Dairy Plant Location with Economies of Size and Market Share Restrictions," *Am. J. Agr. Econ.* 53:461–466, Aug. 1971.

[4] ———, *Optimum Market Organizations of the Fluid Milk Industry in the United States Under Alternative Marketing Strategies*, Oklahoma Agr. Exp. Sta. Tech. Bull. T-133, Oct. 1971.

[5] LASLEY, FLOYD A., *Geographic Structures of Milk Prices*, USDA Agr. Econ. Res. Rep. 255, Sept. 1965.

[6] MACHLUP, FRITZ, *The Basing-Point System*, Philadelphia, The Blakiston Co., 1949.

[7] MANCHESTER, ALDEN C., *Pricing Milk and Dairy Products—Principles, Practices and Problems*, USDA, ERS Agr. Econ. Rep. 207, June 1971.

[8] U. S. Department of Agriculture, Dairy Division, Consumer and Marketing Service, *Federal Milk Order Market Statistics, Annual Summary for 1965*, USDA Stat. Bull. 374, May 1966.

Reliability of Using the Mean Absolute Deviation To Derive Efficient E,V Farm Plans

K. J. Thomson and P. B. R. Hazell

A linear programming approximation using the mean absolute deviation can be used to derive efficient E,V farm plans when a suitable quadratic programming computer code is not available. This note reports a Monte Carlo simulation study designed to test the accuracy of this method, and concludes that it is more reliable than previously thought.

When a farmer's risk aversion depends on an expected income-variance (E, V) utility function, quadratic programming along the lines suggested by Markowitz [6] can be used to derive a set of efficient E,V farm plans from which the farmer may choose [2, 5, 7, 8]. Application of this attractive idea depends, however, on access to a special computer code of which there are few in existence with the desired features and capacity. One way of surmounting this practical difficulty is to use the mean absolute income deviation instead of the income variance and to obtain solution through standard linear programming computer codes with the parametric option. This technique is well known for solving constrained regression problems [1] and has been adapted for the farm planning problem when sample gross margin data are used [3].

When the sample mean absolute deviation (MAD) is used in this way instead of the sample variance, some loss in the reliability of the estimated efficient E,V farm plans is necessarily incurred. Hazell [3, 4] has explored this loss in reliability on the basis of known results about the relative efficiency of the sample MAD compared to the sample variance as estimators of the population variance. This paper, however, intends to show that such arguments can be strengthened through more appropriate definition of the problem. Results of a Monte Carlo simulation experiment, undertaken to test the conclusions of this reexamination, are also reported.

A Reexamination of the Problem

When population values of the means and variance-covariance coefficients of activity gross margins are known, quadratic programming can be used to derive a population efficient E,V boundary. Since in practice the means and variance-covariances must usually be estimated from a time series of gross margin data, only an estimated efficient $\hat{E},\hat{V}$ boundary will be obtained. This is obtained first by ranking farm plans according to V for each level of E and selecting those plans with minimum V occurring at the change in basis as E is parameterized. Second, the estimates $\hat{E}$ and $\hat{V}$ are assigned to these basic farm plans for use by the farmer in selecting a plan according to his own utility function. The second part of this process is subsequent to the derivation of efficient farm plans and may make use of any estimation procedure considered desirable. The first part only employs estimates $\hat{E}$ and $\hat{V}$ to determine efficient farm plans, and the usefulness of the mean absolute deviation model should be judged by its statistical efficiency, vis-à-vis quadratic programming in the selection of a physical farm plan which for given E has minimum V. Since any useful estimator of V will have a sampling variance, the minimization of V by ranking basic feasible farm plans may be subject to error. But the relative efficiency of the sample variance and sample MAD in this ranking procedure is to be distinguished from their relative efficiency in point estimation of V as measured by the ratio of their sampling variances.

This re-analysis of the problem shows that to obtain a true assessment of the reliability of the MAD model, one must compare the performance of the sample MAD with that of the sample variance in ranking farm plans by V. This comparison is complicated by the fact that the ranking ability to be tested will be affected by (1) the actual population variances of the farm plan incomes being estimated, (2) the functional forms of the income distributions, (3) the correlations of the income distributions, and (4) the sample size being used. The Monte Carlo experiment described below attempted to simulate a wide range of such factors.

K. J. Thomson *is a Kellogg Fellow at Iowa State University and* P. B. R. Hazell *is a Young Professional with the World Bank. This research was undertaken while the authors were employed with the Agricultural Adjustment Unit at the University of Newcastle upon Tyne, England.*

The Simulation Experiment

Samples of equal specified size were drawn from two income distributions with equal means, of specified correlation, and with variances in a specified ratio, corresponding to two alternative farm plans with equal E. Both the sample variance and the sample MAD were used to rank the plans on the basis of their estimated variances. An estimate of the probability of each method correctly ranking the plans was made on the results of 500 such simulations for each sample size, correlation, and variance ratio.

The importance of correctly ranking the two plans can be measured in terms of E,V utility. If the E,V utility function for an individual farmer can be written as

$$U(E,V) = f(E) - bV \tag{1}$$

where, for example, $f(E)=aE-bE^2$ when utility is a quadratic function of expected income [6], then the difference in utility resulting from ranking a plan A with parameters E_o and V_A above a plan B with parameters E_o and V_B (rather than the opposite ranking) is

$$U(E_o, V_A) - U(E_o, V_B) = b(V_B - V_A). \tag{2}$$

The b coefficient will differ among individual farmers, but as long as expected utility is a linear function of variance, the difference in utility resulting from ranking the two farm plans with equal E is proportional to the difference in their variances. Further, since the utility function (1) is invariant under a monotone-increasing linear transformation, dividing (2) by bV_B shows the difference in utility to be proportional to

$$1 - V, \quad \text{where}$$
$$V = \frac{V_A}{V_B} \text{ is the variance ratio.} \tag{2.1}$$

Let the probabilities of correctly ranking two farm plans with the sample variance and sample MAD be p_1 and p_2, respectively. Then the loss in utility from using the sample MAD rather than the sample variance to rank plan A above plan B is

$$(p_1 - p_2)b(V_B - V_A). \tag{3}$$

Again, dividing by bV_B, the utility loss for an individual is proportional to

$$(p_1 - p_2)(1 - V). \tag{3.1}$$

The first set of experiments was run with normal distributions of incomes using six variance ratios: 0.4, 0.6, 0.8, 0.9, 0.95, and 0.99. For each correlation and sample size, the total loss in utility using the MAD rather than the variance can be summed over these variance ratios as

$$\sum_i (p_{1i} - p_{2i})b(V_{Bi} - V_{Ai}) \tag{4}$$

where p_{1i} and p_{2i} are the estimated probabilities of the correct ranking of plans for the sample MAD and variance, respectively. V_{Ai} and V_{Bi} are the ith variance values for plans A and B.

By defining V_{Bi} as a constant (actually 1 in this experiment), (4) can be divided by bV_{Bi} without any loss in generality so that the utility loss summed over all variance ratios is always proportional to

$$\sum_i (p_{1i} - p_{2i})(1 - V_i) \tag{4.1}$$

where V_i is the ith variance ratio.

The authors also expressed their results as a percentage of the total utility loss that would arise from using the sample rather than the population variance. Thus, the figure arrived at represents the percentage of additional utility loss in using the sample MAD rather than the sample variance. This percentage is

$$\frac{\sum_i (p_{1i} - p_{2i})(1 - V_i)}{\sum_i (1 - p_{1i})(1 - V_i)} \times 100 \text{ percent}$$

and should be weighed against the computational advantages of using the MAD model rather than quadratic programming.

For the first set of experiments, correlations of −0.6, 0, 0.3, 0.6, and 0.9 and sample sizes of 3, 4, 5, 6, 10, 15, 20, 25, 50, and 100 were used. A second set of experiments, using the same variance ratios and correlations but with sample sizes 5, 15, 25 and 50, was run using as an income distribution a 50–50 mixture of two normal distributions, one with a variance 50 times that of the other. This "contaminated" distribution was considerably less peaked than the normal [10, pp. 448–485] and was used to test performance under conditions involving occasional wide price or yield fluctuations. A third set of experiments employed skew distributions, namely, χ_1^2, χ_3^2, and χ_5^2 with sample sizes 5, 15, and 25. While it is recognized that

Table 1. Total utility loss (arbitrary units) with sample variance over population variance, normal distributions

Correlation	Sample Size 3	4	5	6	10	15	20	25	50	100
−0.6	430.4	412.0	341.8	312.3	243.4	212.3	148.0	154.9	96.2	66.8
0.0	467.3	409.7	368.7	327.6	289.6	260.9	199.6	205.2	118.0	82.8
0.3	493.7	414.8	361.2	338.7	272.9	248.9	182.0	195.8	115.9	80.9
0.6	459.9	389.5	338.9	300.7	249.6	196.1	153.1	145.9	97.6	68.4
0.9	332.1	252.3	211.1	188.0	135.3	108.6	85.4	79.9	52.4	32.4

Table 2. Percentage change in utility loss with MAD over sample variance, normal distributions

Correlation	Sample Size 3	4	5	6	10	15	20	25	50	100
−0.6	0.88	3.61	2.51	0.67	2.75	0.61	7.63	10.45	16.94	14.67
0.0	−2.43	1.90	2.68	2.13	6.04	8.62	1.15	4.97	13.30	9.54
0.3	−0.60	0.65	3.70	2.42	3.95	4.41	−0.98	11.33	8.28	8.40
0.6	0.00	−0.25	5.78	0.36	6.08	7.90	12.14	10.76	15.25	14.18
0.9	0.54	3.96	5.40	7.65	10.79	14.82	11.00	12.39	22.32	27.77

the E,V model is less applicable for skewed income distributions [6], the χ^2 results were obtained to indicate the reliability of the MAD model should skewed distributions be unwittingly encountered in practice.

Results

Table 1 shows the loss in utility resulting from use of the sample variance instead of the population variance in ranking farm plans using normally distributed incomes. As expected, the loss decreases with sample size and with increased absolute correlation between the farm plan incomes. A similar table was constructed showing the loss in utility arising from use of the sample MAD rather than the sample variance. Table 2 shows the percentage of change in utility loss for the case of normally distributed incomes over the range of variance ratios employed. The figures here indicate that the loss in utility from using the sample MAD as opposed to the sample variance increases with both sample size n and absolute correlation $|\rho|$. A more exact analysis showed that 87 percent of the variation could be explained using $\log_{10} n$ and ρ^2 in the equation

$$\text{percent loss} = -7.53 + 10.21 \log_{10} n + 9.09\,\rho^2.$$

Hence, for example, given 15-year sample sizes and a correlation of 0.3, use of the MAD model will increase the loss in utility by about 5 percent above that incurred by use of the sample variance in quadratic programming.

Table 3 shows the percentage change in utility loss in the case of the mixed-normal distribution. Again, about 85 percent of the variation can be explained using the equation,

$$\text{percent loss} = -14.04 + 15.71 \log_{10} n + 10.65\,\rho^2,$$

although the loss is less in absolute terms than for the normal case. The χ^2 results showed even less percentage loss; indeed, the MAD performed better than the sample variance over all, but perhaps because of the small selection of sample sizes, no clear functional form was discernible.

Table 3. Percentage change in utility loss with MAD over sample variance, mixed-normal distributions

Correlation	Sample Size 5	15	25	50
−0.6	−2.25	6.37	7.47	15.72
0.0	0.25	2.48	4.55	12.77
0.3	2.11	2.00	14.78	16.77
0.6	0.99	2.07	20.01	11.63
0.9	2.29	17.86	20.10	20.62

Conclusions

The argument in the first part of this note led the authors to believe that the usefulness of the MAD model could be greater than previously thought because the essential problem was to find the most efficient plan in terms of rank rather than to estimate its parameters. Use of the MAD estimator of variance would, it was hoped, prove only marginally less efficient than that of the sample variance in ranking equal-income plans by V. The results of the Monte Carlo study bear this out, in that the percentage of additional loss in utility incurred by employing the MAD exceeded 10 percent only in cases of high correlation and/or large samples. Since the sample variance is most reliable for these cases (Table 1), the additional absolute loss in utility from using the sample MAD will be low. The percentage of utility loss was also found to be the greatest for normally distributed incomes. The relative performance of the MAD improved with mixed-normal and χ^2 distributions.

These results employed the concept of utility in order to summarize the efficiency of the MAD method for a range of variance ratios while sample size and correlation were held constant. It may be argued that, in practice, as the variance ratios become closer to unity, the farm plans will more closely approximate each other and the correlation between the incomes will increase. If so, either an average ρ will have to be arrived at or a maximum ρ will have to be used to obtain a conservative estimate of the percentage of utility loss incurred. However, Thompson [9, p. 19] claims that there are often a number of very different farm plans ranking closely with optimum plans, and correlation would then not be expected to increase greatly with variance ratio.

References

[1] Ashar, V. G., and T. D. Wallace, "A Sampling Study of Minimum Absolute Deviations Estimations," *Oper. Res.* 11:747–758, Sept.–Oct. 1963.

[2] Camm, B. M., "Risk in Vegetable Production on a Fen Farm," *Farm Economist* 10:89–98, 1962.

[3] Hazell, P. B. R., "A Linear Alternative to Quadratic and Semivariance Programming for Farm Planning Under Uncertainty," *Am. J. Agr. Econ.* 53:53–62, Feb. 1971.

[4] ———, "A Linear Alternative to Quadratic and Semivariance Programming for Farm Planning Under Uncertainty: Reply," *Am. J. Agr. Econ.* 53:664–665, Nov. 1971.

[5] Johnson, S. R., "A Re-examination of the Farm Diversification Problem," *J. Farm Econ.* 49:610–621, Aug. 1967.

[6] Markowitz, Harry M., *Portfolio Selection. Efficient Diversification of Investments*, New York, John Wiley & Sons, Inc., 1959.

[7] McFarquhar, A. M. M., "Rational Decision Making and Risk in Farm Planning," *J. Agr. Econ.* 14:552–563, Dec. 1961.

[8] Stovall, John G., "Income Variation and Selection of Enterprises," *J. Farm Econ.* 48:1575–1579, Dec. 1966.

[9] Thompson, S. C., *An Approach to Monte-Carlo Programming*, Study No. 3, Department of Agriculture, University of Reading, Nov. 1967.

[10] Tukey, J. W., "A Survey of Sampling from Contaminated Distributions," in *Contributions to Probability and Statistics*, ed., I. Olkin, *et al.*, Stanford, Stanford University Press, 1960.

Trend Models of Feeder, Slaughter, and Wholesale Beef Cattle Prices*

JOHN R. FRANZMANN AND RODNEY L. WALKER

Harmonic regressions were fitted to monthly data to provide a low cost alternative means of predicting prices at three market levels in the beef industry and to provide information on time interrelationships among these market levels. The results have limited prediction potential and support preconceived ideas concerning time interrelationships.

UNDER A capitalistic free enterprise system, the market price of beef cattle serves to equilibrate the demand and supply of beef and to channel resources into and out of beef production. Consequently, market price plays a major role in guiding the decisions of producers, feeders, processors, retailers, and other market functionaries.

Resources at each market level often must be committed months before the market forces establish the value of the resulting products. Rational use of productive resources requires the price of the products to be estimated at the time the resources are committed. There is a need, therefore, at each point in the marketing process where exchange takes place to predict at various future points in time.

Prediction has been, and no doubt always will be, an extremely hazardous undertaking. Precise short-run predictions require a detailed understanding of the interrelationships among the variables underlying the demand and supply for beef, as well as knowledge of the characteristics of any combination of nonsystematic elements present in the system. After decades of research with the best economic and statistical tools, no widely accepted short-run price prediction models have been developed and published. Of course, some private concern may have developed such a model and currently may be enjoying the profit returns from its research investment.

Major problems in specifying relationships among the variables, both within and between market levels, have precluded the definition of a suitable model for predictive purposes. Even where identification of the appropriate variables is possible, the difficulties involved in the structural model approach to price predictions are intensified by the absolute lack of certain data series, observational time intervals ill-suited to the model specifications, and physical delays in the release and dissemination of the data which are the input of a predictive model.

Over longer planning horizons, an analysis of trends sometimes proves useful in anticipating important changes in the industry and, therefore, in guiding the longer-run, broader type of decisions. A trend in a series reflecting only a single aspect of an industry is, in general, inadequate; but price trends have an advantage in that they tend to reflect the net effect of the myriad demand and supply forces at work.

In an economy with a high degree of specialization, however, even well-defined price trends are of limited value if they pertain to a single market level. The American beef industry has tended to specialize in retailing, wholesaling, slaughtering and processing, feeding, and cow-calf production. Beef and its products are continually revalued as exchange takes place between each pair of these market levels. Thus, an analysis of price trends in the beef industry is likely to be more useful if any interdependencies among the market levels are identified and measured. This paper reports the results of an analysis of price trends and the relationships among them in the three levels of the beef marketing sector of the economy.

Models for the Feeder, Slaughter, and Wholesale Market Levels

The trend model for each market level—feeders, slaughter, and wholesale—is a regression model incorporating terms that allow for seasonal variation, cyclical variation, and long-term linear trend. On the basis of earlier research on the price trend in slaughter cattle prices [1] and preliminary results of some spectral runs, the cyclical component was defined as having a period of 120 months.[1] The seasonal component, of course, has a period of 12 months.

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JOHN R. FRANZMANN *is associate professor of agricultural economics at Oklahoma State University and* RODNEY L. WALKER *is an agricultural economist with the Farm Production Economics Division of the Economic Research Service, USDA.*

[1] Spectral analysis permits estimation of frequencies within a bandwidth only. The available series are not long enough to provide very accurate estimates of low frequencies such as the cattle "cycle." Hence, the cycle may be somewhat longer or shorter than 10 years.

Feeder cattle

Data used to estimate the parameters of the feeder cattle model were the monthly weighted average cost per cwt. for all weights and grades of stocker and feeder steers shipped at Kansas City, covering the period of January 1925 through December 1969. To adjust for inflationary and deflationary forces and to reflect relative real prices among agricultural production alternatives, the series was divided by the Index of Prices Received by Farmers for All Farm Products, 1910–14 = 100. In each of the trend models t is a time trend variable with values 0, 1, 2 · · · with $t=0$ at January 1921.

On the basis of the foregoing model and data, the following equation was estimated:[2]

$$
\begin{aligned}
\hat{P}_f = {} & 5.43936 + \underset{(40.87)}{0.00812t} - \underset{(-14.01)}{0.62209 \sin 3t} \\
(1) \qquad & + \underset{(26.05)}{1.5536 \cos 3t} + \underset{(10.06)}{0.44348 \sin 30t} \\
& + \underset{(0.93)}{0.04107 \cos 30t}.
\end{aligned}
$$

$$R^2 = 0.83$$

Throughout this paper the numbers in parentheses are t statistics. It is clear from the magnitudes of this statistic that each coefficient is statistically significant with the exception of that associated with cos $30t$. However, both the sine and cosine are needed to obtain the phase angle correctly and, hence, the recommendation of Waugh and Miller [4, p. 424] is followed.

Slaughter cattle

Data used to estimate the parameters of the slaughter cattle model were the monthly average cost per cwt. of cattle slaughtered under federal inspection divided by the Index of Prices Received by Farmers for All Farm Products, 1910–14 = 100. The time span covered was from January 1921 through December 1969.

On the basis of the postulated model and the foregoing data, the following equation was estimated:

$$
\begin{aligned}
\hat{P}_s = {} & 5.25636 + \underset{(50.42)}{0.00720t} - \underset{(-14.43)}{0.49010 \sin 3t} \\
(2) \qquad & + \underset{(29.42)}{1.00516 \cos 3t} + \underset{(10.88)}{0.36839 \sin 30t} \\
& - \underset{(-7.92)}{0.26806 \cos 30t}.
\end{aligned}
$$

$$R^2 = 0.87$$

In this instance, each of the coefficients is statistically significant in the present form of the equation, and the coefficient of determination is slightly greater than the estimate for the feeder cattle model.

Wholesale beef

Data used to estimate the parameters of the wholesale beef model were the monthly average wholesale value of the beef carcass and by-products per cwt. divided by the Wholesale Price Index, 1910–14 = 100, covering the period of January 1949 through December 1969. The wholesale value series is only available beginning with January 1949; hence, the analysis at the wholesale level was conducted with a much shorter series of data.

On the basis of the postulated model and the foregoing data, the following equation was estimated:

$$
\begin{aligned}
\hat{P}_w = {} & 13.07612 - \underset{(-5.50)}{0.00511t} + \underset{(1.90)}{0.17501 \sin 3t} \\
(3) \qquad & + \underset{(9.07)}{0.86851 \cos 3t} - \underset{(-1.50)}{0.13556 \sin 30t} \\
& - \underset{(-1.67)}{0.15119 \cos 30t}.
\end{aligned}
$$

$$R^2 = 0.40$$

In the above form, the seasonal terms did not achieve statistical significance at the customary levels. This may not be surprising in view of the status of the product at this stage of the marketing process and the more monopolistic structure of the wholesale markets in general, which would introduce greater short-run price stability. Judgment, however, is deferred until the equation is transformed in such a manner to estimate the relevant phase angles.

[2] For a 10-year cycle, the period, T, must be 120 months $=360°$; therefore, $2\pi \cdot t/T = 2\pi t/120 = 3t$. Similarly, for the seasonal component, the period must be 12 months $=360°$ and $2\pi t/T = 2\pi t/12 = 30t$.

Measurement of Lags[3] Among Market Levels

Equations of the form

$$(4) \qquad Y_t = \sum_i a_i \cos x_i t + \sum_j b_j \sin x_j t$$

are useful in obtaining the "best" regression estimates of the parameters, a_i and b_j, and for projecting the established trends. However, if there is reason to believe that there are any lags either cyclically or seasonally, then these lags can be estimated by means of the transformation:

$$(5) \qquad a \cos x + b \sin x = \sqrt{a^2 + b^2} \cos (x - \arctan b/a)$$

Thus, equations (1), (2), and (3) are equivalent to

$$(6) \qquad \begin{aligned} \hat{P}_f = 5.43936 + &\underset{(40.87)}{0.00812t} + \underset{(20.90)}{1.31219} \cdot \cos (3t - 28° 18') \\ &+ \underset{(7.15)}{0.44538} \cos (30t + 84° 42'); \end{aligned}$$

$$(7) \qquad \begin{aligned} \hat{P}_s = 5.2564 + &\underset{(50.42)}{0.00720t} + \underset{(23.22)}{1.11827} \cdot \cos (3t - 27°) \\ &+ \underset{(9.52)}{0.4556} \cos (30t + 126° 3'); \end{aligned}$$

$$(8) \qquad \begin{aligned} \hat{P}_w = 13.07612 - &\underset{(-5.50)}{0.00511t} + \underset{(6.67)}{0.88597} \cdot \cos (3t + 11° 24') \\ &+ \underset{(1.59)}{0.20306} \cos (30t + 221° 53'). \end{aligned}$$

In the alternate form, all of the coefficients appear to be statistically significant with the exception of the coefficient associated with the seasonal term of the wholesale price equation. In fact, with the given specification and the length of the data series available, the equation does not adequately describe the wholesale series.

Despite the weakness in the wholesale beef function, the lead-lag relationships among the three market levels can be investigated through an examination of the cyclical and seasonal phase angles. These relationships are depicted in Figure 1.

According to economic theory, the demand for resources is derived from the final consumer demand, which finds its first market expression at the retail level. The derived nature of demand and the differences in market structure among the three market levels suggest that the wholesale level would lead the slaughter level and the slaughter level would lead the feeder level. In general, the empirical evidence bears out such a relationship. In terms of the cyclical fluctuations, wholesale prices lead slaughter prices by 38° 24′, which, when converted to the time dimension, is equivalent to a lead of 12.8 months. In turn, for the cyclical component, slaughter prices lead feeder prices by 1.3° or by

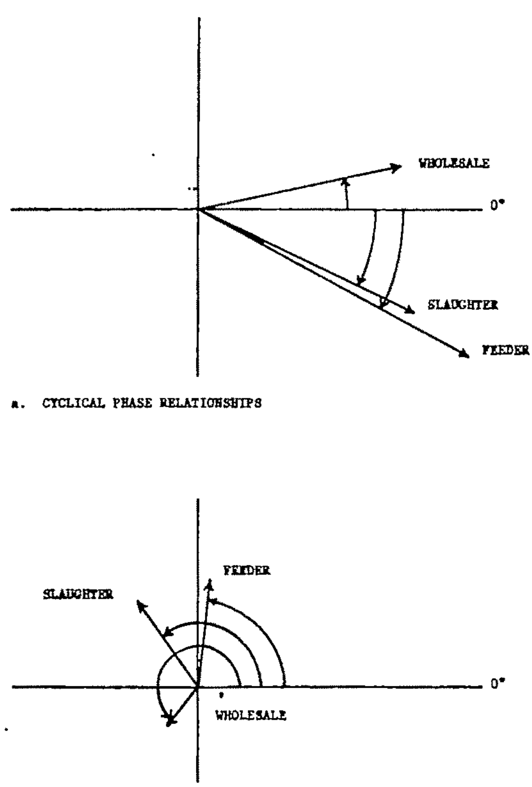

Figure 1. Phase relationships for feeder, slaughter, and wholesale prices of beef

[3] The term "lag" here refers to the extent to which the function is displaced from the arbitrary origin. That is, a sine curve ordinarily has a value of zero at the origin. If it should have a value of 1/2 at the origin, then the function will have a lag of 30°. Such lags are useful in comparing the seasonal component or the cyclical component between two equations.

only 0.43 month. When the nature of the data used in the analyses is considered, the cyclical component of the slaughter and feeder series is, practically speaking, coincident.

For the seasonal relationships, again, wholesale price leads slaughter price and slaughter price leads feeder price. The wholesale lead was estimated at 95°50′ or approximately three months. The lead of the slaughter series over the feeder series was estimated at a little more than 41° or about $1\frac{1}{3}$ months.

In view of the poor statistical fit of the model for wholesale prices, little can be concluded with regard to the magnitude of its phase angle relationships. The phase angle associated with the seasonal component has no real meaning since the seasonal coefficient was statistically nonsignificant, and with a coefficient of determination of 0.40 the magnitude of the cyclical phase angle may be suspect.

Interpretation of the Coefficients

Coefficients of the cyclical and seasonal terms in equations (6), (7), and (8) are also of some interest. For the cyclical component, the coefficient is greatest for the feeder price series and smallest for the wholesale price series, apparently reflecting differences in the market structures among the market levels. It is generally conceded that the feeder level more nearly approximates a purely competitive structure and, hence, is subject to wider price variability than are the more monopolistically competitive slaughter and wholesale levels.

In terms of the shorter-run seasonal effects, there appeared to be little difference between the feeder and slaughter levels. The coefficient of the seasonal term in the wholesale function, however, was less than half the magnitude of the similar term in the slaughter and feeder functions. This would seem to imply that there is greater seasonal stability at the wholesale level than at either of the other market levels investigated. These results are consistent with the authors' preconceptions concerning price relationships among market levels. Thus, Waugh [3, p. 20] states:

> Briefly, if the spreads were a constant percentage of the retail price, the "flexibilities" of retail prices and farm prices would be equal. . . . On the other hand, if the spreads were absolute amounts in dollars and cents, the prices would be more flexible at the farm than at retail.
>
> * * * *
>
> Many studies of this matter in the Department of Agriculture suggest that the price spreads are neither constant percentages nor constant absolute amounts, but somewhere in between the two. In such cases, the farm price is more flexible than the retail price.

Coefficients associated with the linear trend components reveal the feeder and slaughter series are trending upward at about the same rate. The wholesale series, however, indicates a *negative* trend, posing a difficult problem in interpretation. Taken at face value, the trends in wholesale price and slaughter price would converge about November 1973, a virtually impossible event.

Two more plausible explanations may be offered. The first is based on the poor statistical quality of the wholesale function. That is, if the function's error term were to be reduced through the incorporation of additional terms and/or the addition of a greater number of observations over time, the new and more accurate estimate of the trend may be positive and consistent with the trends at the other market levels. Thus, it is not possible to obtain a good comparison of the wholesale function with the others.

The second interpretation is based on the concept that when dealing with a finite amount of data, a linear trend may, in fact, be only a representation of a fluctuation of long period and low amplitude. Thus, Granger [2, p. 151] states,

> . . . when dealing with a sample $\{y_t, t=1, \cdots, n\}$ . . . the straight line $a+bt$, $t=1, \cdots, n$ is virtually unrecognizable from the function $a \cos t/N + bM \sin t/M$ where $N \gg n$, $M \gg n$.

Under such an interpretation it is possible to state that the wholesale series is in the downswing phase of a very low frequency component with a very long period, and that the slaughter and feeder series may be in the upswing phases of some low frequency component. If this second interpretation is the more plausible, then inferences of some consequence to the livestock industry may be involved, depending on the frequency, amplitude, and phase angle of the component at each market level.

Prediction Potential

In assessing the prediction potential of harmonic models, attention should be directed to two aspects of the problem—ability to detect the cyclical and seasonal turning points and

ability to estimate the magnitude of price changes that are imminent with negligible error.

The statistical properties of the feeder and slaughter tolerances indicate an ability to detect turning points within acceptable tolerances for decisions with rather long-run planning horizons. They are, no doubt, inadequate for decisions involving planning horizons of less than, say, three months. In view of the poorer quality of the wholesale function, estimates for the turning points and the phase angle are more suspect. However, because of the time shift between the wholesale and slaughter levels, some useful information may be provided. On the basis of monthly data, these models do not appear to provide sufficiently accurate estimates of the seasonal leads and lags to be of predictive value over the short run. Short-run predictions would be better handled by models reflecting short-run supply-demand phenomena rather than by a mechanistic trend model.

No very definitive statement can be made concerning the ability of a function to predict specific price levels without knowledge of the kind of accuracy demanded by various sectors of the livestock and beef industry. Ultimately, the model is judged on how well it performs relative to other available models capable of predicting over the same planning horizon. However, a test against recent realized values is of some use; therefore, estimates for the period of January 1970 to December 1971 were made and compared with the realized prices. Results of this test are presented in Table 1.

The results reported in Table 1 emphasize the hazards of attempting to predict short-run prices from the trend models. This is particularly true for the feeder model where the errors predominantly exceed $1 per cwt. The same difficulty is encountered with the two remaining market levels, although the errors associated with slaughter cattle average closer to $0.50 per cwt. and the errors associated with the wholesale market average close to $0.40 per cwt. over the projected time intervals. However, these are *long-term* trend models and, used as such, can be expected to be of some potential value to the livestock and meat industry. Where short-run estimates are needed, other methods undoubtedly will prove superior.

Table 1. Comparison of the realized and projected deflated price per cwt. of feeder cattle, slaughter cattle, and wholesale beef, January 1970–December 1971

Date	Feeder			Slaughter			Wholesale		
	Proj.	Real	Diff.	Proj.	Real	Diff.	Proj.	Real	Diff.
	$/cwt.			$/cwt.			$/cwt.		
1970									
Jan.	11.88	10.26	+1.62	10.32	9.36	+0.96	10.52	11.05	−0.53
Feb.	12.12	10.83	+1.29	10.56	9.44	+1.12	10.50	11.01	−0.51
Mar.	12.29	11.54	+0.75	10.80	10.09	+0.71	10.53	11.02	−0.49
Apr.	12.35	11.53	+0.82	11.00	10.35	+0.65	10.61	10.83	−0.22
May	12.28	11.12	+1.16	11.09	10.12	+0.97	10.73	10.65	+0.08
June	12.11	10.98	+1.13	11.06	10.23	+0.83	10.85	10.92	−0.07
July	11.89	10.32	+1.57	10.91	19.19	+0.72	10.96	10.71	+0.25
Aug.	11.67	10.42	+1.25	10.69	10.28	+0.49	11.03	10.75	+0.28
Sept.	11.52	10.32	+1.20	10.45	9.96	+0.49	11.04	10.40	+0.64
Oct.	11.47	10.83	+0.64	10.26	9.91	+0.35	10.99	10.33	+0.66
Nov.	11.54	10.38	+1.16	10.16	9.62	+0.54	10.90	10.48	+0.42
Dec.	11.70	10.40	+1.30	10.18	9.53	+0.65	10.81	10.43	+0.38
1971									
Jan.	11.91	10.86	+1.05	10.31	9.96	+0.35	10.73	N.A.	—
Feb.	12.10	11.16	+0.94	10.52	10.46	+0.06	10.68	N.A.	—
Mar.	12.21	11.23	+0.98	10.73	10.60	+0.13	10.69	N.A.	—
Apr.	12.22	11.37	+0.85	10.89	10.67	+0.22	10.74	N.A.	—
May	12.10	11.11	+0.99	10.95	10.54	+0.41	10.83	N.A.	—
June	11.88	10.63	+1.25	10.88	10.69	+0.19	10.93	N.A.	—
July	11.60	10.60	+1.00	10.70	10.51	+0.19	11.01	N.A.	—
Aug.	11.34	11.29	+0.05	10.45	10.77	−0.32	11.05	N.A.	—
Sept.	11.14	11.25	−0.11	10.18	10.80	−0.62	11.03	N.A.	—
Oct.	11.04	11.87	−0.83	9.96	10.40	−0.44	10.95	N.A.	—
Nov.	11.06	11.80	−0.74	9.84	10.21	−0.37	10.84	N.A.	—
Dec.	11.18	11.90	−0.72	9.83	10.64	−0.81	10.71	N.A.	—

The standard error of the estimate provides an objective measure of the quality of each relationship, and potential users of the relationships can employ this statistic to judge whether the predictions are likely to meet their individual needs. The standard error of the estimate was \$0.7194 for the feeder equation, \$0.5804 for the slaughter equation, and \$1.0060 for the wholesale equation.

Examining the residuals is yet another way to evaluate the equations. Using the slaughter equation for illustrative purposes, the residuals ranged from a −\$1.4858, the estimate for October 1921, to a +\$2.3082, the estimate for July 1932. Apart from the extremes, 30 percent of the estimated values were within ±\$0.25 of the observed values and 60 percent were within ±\$0.50 of the observed values. A similar analysis for the feeder and wholesale equations would yield poorer results.

Summary

Knowledge of the expected future course of the prices of beef cattle and their products can be useful to members of the industry in planning output levels and, hence, the levels of resource use most likely to yield a profit. Trend analysis is one of a set of alternative means of estimating the future course of prices in the beef cattle industry.

In the work reported here, equations were estimated for the feeder, slaughter, and wholesale levels of activity, using a model which included a linear trend, a 10-year cycle, and seasonal component. Regression coefficients were estimated using the general Fourier form of the model. The results were then transformed into cosine functions to obtain estimates of the phase angle relationships among the several market levels.

The results indicate that, in general, wholesale prices lead slaughter prices and slaughter prices lead feeder prices, both cyclically and seasonally. However, the phase angle relationship between the feeder and slaughter levels may be too small to be of practical predictive value in a model based on monthly data.

Magnitudes of the coefficients tend to support the generalized notion that the wholesale and slaughter levels are more monopolistic than is the feeder level. The degree of monopoly power, however, is not measured by such a model formulation.

The trend models are not judged to be of sufficient quality for decisions over short planning horizons. For planning horizons of a year or more, the functions may prove of some value to the industry, particularly because of the low cost involved in making the projections.

References

[1] Franzmann, John R., "Cattle Cycles," Oklahoma Agr. Exp. Sta. Journal Article 2207, presented at the Southern Agricultural Economics Association, Jacksonville, Fla., Feb. 1–2, 1971.

[2] Granger, C. W. J., in association with M. Hatanaka, *Spectral Analysis of Economic Time Series*, Princeton, Princeton University Press, 1964.

[3] Waugh, Frederick V., *Demand and Price Analysis. Some Examples from Agriculture*, ERS, USDA Tech. Bull. 1316, Nov. 1964.

[4] ———, and Morton M. Miller, "Fish Cycles: A Harmonic Analysis," *Am. J. Agr. Econ.* 52:422–430, Aug. 1970.

Investments in Agricultural Processing for Rural Development in Oklahoma*

GERALD A. DOEKSEN AND DEAN F. SCHREINER

A simulation model measured the employment impact of investment in agricultural processing industries. Large short- and long-run multipliers and a low investment cost per job placed agricultural processing industries in a favorable position. However, a potential industry growth analysis indicated that this sector alone cannot meet rural development objectives.

INDUSTRIALIZATION has frequently been advocated as a means of solving the surplus labor and low-income problems typifying many rural areas. This has been especially argued when a region (or country) is a large producer and exporter of primary products, i.e., minerals, energy, and agricultural and forest products. The argument follows that regional development in terms of increased incomes and employment opportunities is enhanced if the primary material is carried through additional reduction and/or processing levels before exporting. The objective of this paper is to measure the impact from processing available agricultural products on development objectives in a rural state. More specifically, attention is directed to determining the short- and long-run employment benefits from private investment in the agricultural processing sector, measuring the short- and long-run private investment cost per job created by agricultural processing, and evaluating the impact on state employment of increased growth in the agricultural processing sector.

Recent research articles report that agricultural processing[1] is becoming more decentralized. Haren in a recent article [6] analyzed rural industrial growth in the 1960's and concluded, "Further gains in related sources of basic employment should result from an anticipated continuation of the decentralization under way in food processing, packaging, and distribution" [6, p. 436]. Goodstein [5], who studied employment growth in the South between 1940 and 1960, concluded that non-urban areas played a more significant role than did the urban areas in the expansion of manufacturing in terms of changes in both relative shares and absolute increments. An analysis of manufacturing in the Great Plains by Schreiner and Warner [10] reasoned that in general *food processing* is not as heavily concentrated in SMSA's as manufacturing as a whole. The National Planning Association [9] projects that employment in the *food and kindred products* sector will increase 104,800 jobs, or 5.8 percent, from 1968 to 1980. If this growth occurs and if food and kindred products industries continue to decentralize, it will be important to know the potential impact on rural areas.

Regional planners and economists are interested in measuring both the short-run and the long-run impacts from potential investments. Regional models such as economic base and input-output are static in nature and do not measure the effects of long-run adjustments. Partial analyses such as case studies measure the impact created by the location of a particular manufacturing plant. Regional planners and economists are interested in static and partial studies, but they also want to know the impact of alternative investment strategies over extended periods of time. This paper attempts to evaluate the total long-run effects from further growth in the agricultural processing sector on rural development objectives. First, the authors discuss the model formulation in terms of a state social accounting system and simulation model. Second, the procedure and empirical results are presented and discussed for evaluating the three specific objectives.

Model Formulation

For this study the Oklahoma economy was divided into 12 endogenous sectors and 5 exogenous ones. Endogenous sectors were: (1) Livestock and Livestock Products, (2) Crops,

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[1] The terms *agricultural processing* and *food and kindred products* both refer to the SIC code 20.

GERALD A. DOEKSEN *is an agricultural economist for the Economic Development Division, Economic Research Service, USDA, stationed at Oklahoma State University.* DEAN F. SCHREINER *is an associate professor of agricultural economics at Oklahoma State University.*

(3) Agricultural Processing, (4) Petroleum Processing, (5) Machinery, (6) Other Manufacturing, (7) Mining, (8) Transportation, Communications, and Public Utilities, (9) Real Estate, Finance, and Insurance, (10) Services, (11) Wholesale and Retail Trade, and (12) Construction. Exogenous sectors were: (1) Federal Government, (2) State and Local Governments, (3) Private Capital Formation, (4) Households, and (5) Exports.

Social accounting system

The Oklahoma social accounting system is divided into three main accounts: (1) a capital resource account, (2) an interindustry account, and (3) a human resource account. An outline of this accounting system is presented in Figure 1.

The capital account includes a capital coefficient matrix, sector capacity levels, capital-output ratios, capital unit matrix, capital stock matrix, inventory coefficients, depreciation rates, and an investment matrix.[2] The interindustry account consists of three basic parts: a transaction table, a direct coefficient table, and a direct and indirect coefficient table. The human resource account includes data on employment, income, wages, and population.

Simulation model[3]

The simulation model is formulated around the basic Leontief input-output system.[4] The complete multi-sector recursive model consists of 51 major equations, many of which are disaggregated into sub-equations with one sub-equation for each endogenous sector in the Oklahoma economy. Thus, the entire system contains more than 300 equations. The model was formulated in Fortran and can be run on the computer at a relatively low cost. The researcher can experiment with the model by changing variables and measuring their impact. The model can be generalized as comprising

[2] For a definition of terms and a complete presentation of the capital analysis, see [2].

[3] For a complete presentation of the simulation model, see [1].

[4] The model for Oklahoma is similar to other simulation models. For example, see [8].

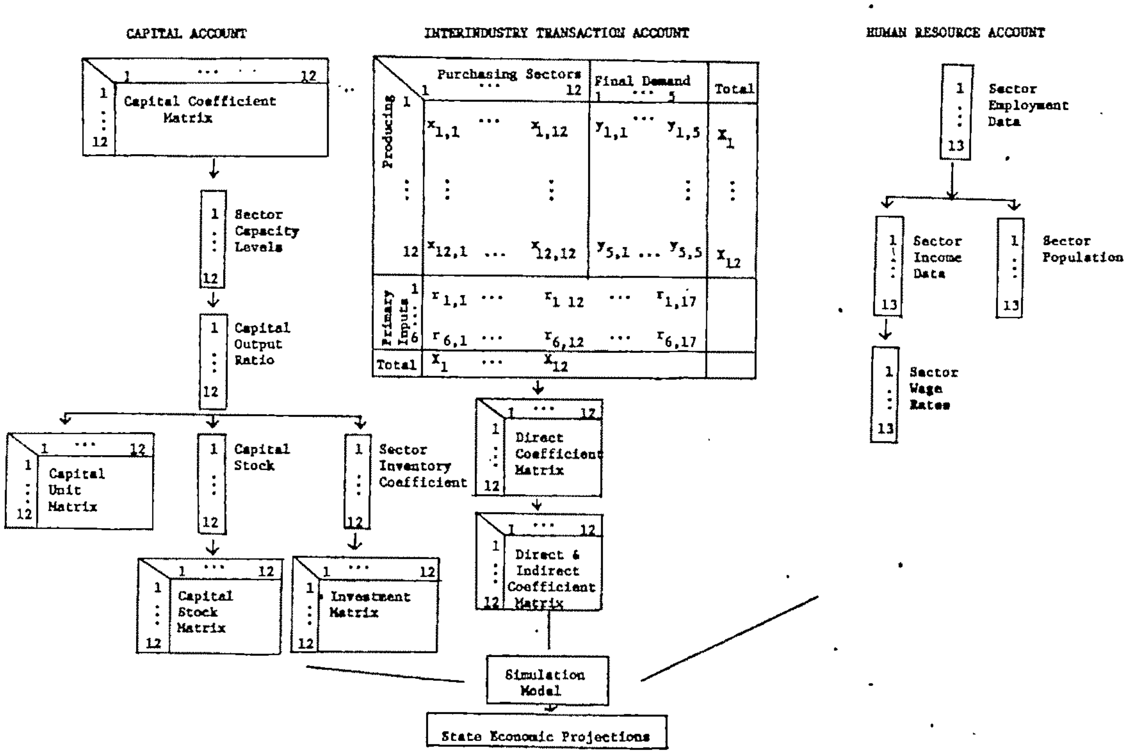

Figure 1. The Oklahoma social accounting system

three main subparts: (1) estimating final demand, (2) determining sector output, and (3) deriving state projections of economic variables. First, equations were developed to estimate final demand; each final demand equation was determined from prior research and economic theory. For example, the private capital formation equation was specified using the accelerator principle. Household durable purchases were a function of population and disposable income; exports for the state were a function of U. S. demand. Secondly, after final demand was estimated, output requirements by endogenous sector were determined using the input-output model. Thirdly, sector output estimates were used to derive projections of state economic variables. The model incorporates elements of economic growth and development through increased capital investment (using capital-output ratios and changes in capital-output ratios), through increased human resource productivity (labor-output ratios, changes in labor-output ratios, and changes in wage rates), and through changes in current activity (changes in population, government expenditures, and exports).

Procedure[5] and Empirical Results

The social accounting system was developed for 1963, and the simulation model was used to project levels of state economic variables. Wage and salary employment, proprietor employment, wage and salary payments, proprietor income, disposable income, per capita income, gross state product, federal government revenue, and state and local government revenue were projected from 1963 through 1980. Analysis consisted of measuring the impact of alternative courses of action on employment and income.

Evaluation of the short-, intermediate-, and long-run employment benefits from private investment in the agricultural processing sector

The procedure used to determine the short-, intermediate-, and long-run employment benefits from private investment in agricultural processing was to assume a $1 million investment in that sector in 1970.[6] For comparison, simulation runs were made for the other endogenous sectors to determine the impact of similar investments.[7] This impact was measured in terms of new employment created in 1970 and through 1980.

The growth process leads to short-, intermediate-, and long-run employment effects from a million dollar investment as outlined in Table 1.

During the first year, three effects arise due to the $1 million capital investment. The *direct effect* measures employment generated directly in the sector due to increased production, while the *indirect effects* arise as the sector which increases production demands additional goods and services from all endogenous sectors. In turn, these sectors will increase their demands for goods from other industries, and the reverberations will continue until the economy completely adjusts. All repercussions of increased production are included in the indirect effects. Another employment effect arising during the first year is the *capital formation effect* which includes employment generated by the $1 million capital investment. Employment created through capital formation is closely associated with the construction and durable goods sectors.

[5] For a more detailed explanation of the methodology involved, see [4].

[6] The amount ($1 million) was arbitrarily chosen to represent an investment in the agricultural processing sector as well as all endogenous sectors. The results (multipliers and cost per 100 jobs) would be similar for any amount chosen. If, for example, $2 million had been invested in the agricultural processing sector, the direct effect and the direct and indirect effects would double and consequently would not change the employment multipliers.

[7] The million dollar capital investment was reflected in the capital equation of the simulation model. The amount of production generated in each sector from the investment was determined by the capital-output ratio. The increased production was assumed exported if the sector were a net exporter and consumed in the state if the sector were a net importer. Both the capital investment and increased production were assumed to occur simultaneously in 1970.

Table 1. Short-, intermediate-, and long-run effects from investment in each endogenous sector

Short-Run Effects	Intermediate-Run Effects	Long-Run Effects
1. Direct Effect	1. Direct Effect	1. Direct Effect
2. Indirect Effect	2. Indirect Effect	2. Indirect Effect
3. Capital Formation Effect	3. Induced Consumption Effect	3. Induced Consumption Effect
	4. Induced Capacity Effect	

During the intermediate period four employment effects occur throughout the state economy. Direct and indirect effects resulting from sector production remain as production continues into the intermediate period. The *induced consumption effect* arises as the increased production yields a greater amount of regional personal income. A proportion of the increased income is spent on regional consumer goods and services.[8] Another employment effect of the intermediate period is the *induced capacity effect*. It is due to "induced investment" from changes in output of all other sectors and is largest during the first and second years following the initial change in production. It eventually tapers off to zero over a period of years.

With capital formation effect reduced to zero in the short run and the induced capacity effect reaching zero after a period of years, all that remain in the long run are the direct and indirect production effects and the induced consumption effects. Long-run effects indicate equilibrium levels after the initial production increase. These effects can be easily converted into employment impacts and multipliers. Employment effects and multipliers are presented in Table 2; column (1) lists the direct employment effects for each sector. The direct effect indicates the number of man-year equivalents employed in sector production from a $1 million capital investment. The largest direct effects occur in wholesale and retail trade and in services with 226 and 221 men, respectively, employed per million dollars of capital investment. The sectors with the smallest direct effects are petroleum; transportation, communication, and public utilities; and mining.

Direct and indirect employment effects listed in column (2) of Table 2 are computed by considering the repercussions on employment in all sectors caused by the initial change in production. Agricultural processing has the largest direct and indirect effect with 491 jobs created from the initial production change. Construction, wholesale and retail trade, and services generate 359, 291, and 288 jobs, respectively. Short-run production employment multipliers are listed in column (8). Each multiplier indicates the change in direct and indirect employment generated throughout the Oklahoma economy by a one-unit change in production employment in the specified sector. The petroleum processing sector has the largest employment multiplier, 7.25, which results from its large interaction with other sectors, particularly mining and manufacturing. Agricultural processing has the second largest employment multiplier—6.29. Interpretation of this multiplier is that for each man-year directly employed in the agricultural processing sector for delivery to final demand, a total of

[8] Leakage effects have been described in [7] and [11].

Table 2. Short-, intermediate-, and long-run employment impacts and multipliers from a million dollar investment in industry capacity, Oklahoma, 1970

	Direct Employment Effect[a] (1)	Direct and Indirect Employment Effect[a] (2)	Capital Formation Effect[a] (3)	Total Short-Run Effect[a] (4)	Total Second Year Effect[a] (5)	Total Third Year Effect[a] (6)	Total Long-Run Effect[a] (7)	Short-Run Production Employment Multiplier[b] (8)	Short-Run Total Employment Multiplier[c] (9)	Intermediate-Run Multiplier (Second Year)[d] (10)	Intermediate-Run Multiplier (Third Year)[d] (11)	Long-run Employment Multiplier[e] (12)
Livestock	59	140	68	208	332	258	121	2.37	3.52	5.63	4.37	2.05
Crops	111	128	75	213	301	228	80	1.24	1.92	2.71	2.05	.72
Agricultural Processing	78	491	65	556	982	901	488	6.29	7.13	12.59	11.55	6.25
Petroleum	12	87	64	151	325	255	75	7.25	12.58	27.08	21.25	6.25
Machinery	76	154	67	221	353	296	196	2.02	2.91	4.64	3.89	2.58
Other Manufacturing	82	153	68	221	356	303	257	1.87	2.60	4.34	3.69	3.13
Mining	32	68	78	146	252	181	67	2.12	4.56	7.87	5.66	2.10
Transportation, Communication, and Public Utilities	24	37	59	96	177	120	40	1.54	4.00	7.37	5.00	1.66
Real Estate, Finance, and Insurance	80	122	67	189	282	219	127	1.52	2.36	3.53	2.74	1.59
Services	221	288	64	352	486	442	359	1.30	1.59	2.19	2.00	1.62
Wholesale and Retail Trade	226	291	71	362	498	444	353	1.29	1.60	2.20	1.96	1.56
Construction	152	359	62	421	662	610	391	2.36	2.76	4.36	4.01	2.57

[a] Man-year equivalents.
[b] These multipliers were computed by dividing the direct effect (column 1) into the direct and indirect effect (column 2).
[c] These multipliers were computed by dividing the direct effect (column 1) into the direct, indirect, and capital formation effect (column 4).
[d] These multipliers were computed by dividing the direct effect (column 1) into the intermediate effects (columns 5 or 6).
[e] These multipliers were computed by dividing the direct effect (column 1) into the long-run effect (column 7).

5.29 additional man-years is generated throughout the economy.[9]

Direct capital formation effects of each sector are listed in column (3) of Table 2. These figures indicate the man-years required to produce the $1 million capital investment for that sector. Capital formation effects are somewhat similar for all sectors, ranging from 59 to 78 man-years. Total man-years resulting from capital formation and increased production are listed in column (4). Agricultural processing and construction have the largest total effects with 556 and 421 man-years, respectively. Total short-run employment multipliers listed in column (9) indicate changes in direct, indirect, and capital formation employment generated throughout the Oklahoma economy by a one-unit change in production employment in that sector. Petroleum processing has the largest total short-run employment multiplier, 12.58, indicating that for each man-year employed directly in increased petroleum processing in 1970, a total of 12.58 man-years would be employed throughout the economy in both production and direct capital formation activities.

Intermediate-run effects and multipliers are found in columns (5), (6), (10), and (11) of Table 2. The activity generated in the short run creates additional production demands from all other sectors. This additional production requires additional plant capacity which is constructed in the intermediate years. Most of the additional capacity is constructed in 1971 and 1972 and tapers off to zero after a brief period of years. Also occurring during the intermediate years are induced consumption effects created by increased consumer income. Man-year requirements for each year are listed in columns (5) and (6); sectors with the largest man-year requirements are agricultural processing, construction, wholesale and retail trade, and services. Intermediate-run multipliers are listed in columns (10) and (11) where it can be seen that petroleum, agricultural processing, and mining have the largest intermediate-run multipliers. Each multiplier indicates the total change in employment in 1971 and 1972 resulting from a production increase of one man-year in 1970.

Long-run employment effects and multipliers are presented in columns (7) and (12) of Table 2. With the capital formation effect occurring during the initial year and the capacity effects tapering off to zero during the intermediate years, only the total production and induced consumption effects remain in the long run. Total employment generated for each sector in 1980 as a result of 1970's increased production is listed in column (7). Agricultural processing, construction, services, and wholesale and retail trade have the largest long-run employment requirements. Long-run employment multipliers are listed in column (12), each multiplier indicating the total employment generated in 1980 by the one man-year production employment in 1970. Petroleum processing, agricultural processing, and other manufacturing have the largest long-run employment multipliers at 6.25, 6.25, and 3.13, respectively. Long-run employment multiplier for crops is 0.72, which reflects the rapid increase in technology used in the crop sector and the small amount of interaction of crops with other sectors.

Evaluation of the short- and long-run private investment cost per job created by expansion in the agricultural processing sector

The procedure for this evaluation was accomplished in three steps. First, the capital-output and labor-output ratios from the agricultural processing sector were used to determine the number of man-years directly employed in production from a $1 million capital investment in sector capacity. The number of man-years divided into $1 million yielded the capital investment per direct job. Second, the simulation model determined the number of jobs created directly and indirectly in the short run and then converted that number to a per-job investment cost.[10] Third, the long-run employment impact was determined from the simulation model and converted to a per-job investment cost. Similar calculations for the remaining endogenous sectors were conducted for comparison purposes.

The direct investment cost per 100 jobs

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[9] Marginal changes in output and employment due to the additional investment are assumed equal to average changes for 1970. New output is assumed forthcoming from all indirect sources. A later section allows substitution of the in-state processing for primary agricultural product exports.

[10] Indirect private investment costs due to "induced capacity" were not included. It was assumed that because indirect investment is "induced" it would automatically be forthcoming with no further decision making involved. The development objective is not to minimize total private investment but rather to compare total state employment generated from investment in agricultural processing with investment in other alternative sectors.

created is presented in column (1) of Table 3. For example, to employ 100 men directly in the agricultural processing sector, $1,282,000 (1963 prices and average capital-output ratio) must be invested in that sector. The wholesale and retail trade sector has the lowest direct short-run investment requirements per 100 jobs.

The direct investment cost per 100 jobs created directly and indirectly in the short-run by industry is found in column (2) of Table 3. These costs indicate the direct investment needed in a particular sector to create 100 jobs directly and indirectly. Jobs are directly created in the sector receiving the investment; however, employment created by the interaction of sectors is also included, thus capturing employment changes in all sectors. For example, if $204,000 were invested in agricultural processing, 100 jobs would be created throughout the economy in the short-run, thus indicating that the agricultural processing sector has the lowest short-run direct-indirect investment requirement per 100 men employed.

The investment costs per 100 jobs created in the long run are presented in column (3) of Table 3. In the long run, employment is increased directly, indirectly, and induced.[11] Each figure in column (3) indicates the amount of direct investment required in 1970 to increase employment throughout the economy by 100 jobs in 1980. The agricultural processing sector requires $205,000 of direct investment in 1970 to create 100 jobs in 1980.

Table 3. Direct short-, intermediate-, and long-run investment cost per 100 jobs created in Oklahoma, 1970

Sector	Investment cost per 100 jobs directly created in the short run (1)	Investment cost per 100 jobs directly and indirectly created in the short run (2)	Investment cost per 100 jobs created directly, indirectly, and induced in the long run (3)
	(Thousands of Dollars in 1963 Prices)		
Livestock and Livestock Products	1,695	714	826
Crops	901	724	1,250
Agricultural Processing	1,282	204	205
Petroleum Processing	8,333	1,149	1,333
Machinery, Except Electrical	1,316	649	510
Other Manufacturing	1,219	654	389
Mining	3,125	1,471	1,492
Transportation, Communication, and Public Utilities	4,167	2,703	2,500
Real Estate, Finance, and Insurance	1,250	830	787
Services	452	347	279
Wholesale and Retail	443	344	283
Construction	658	279	256

Evaluation of the impact on state employment from expected growth in the agricultural processing sector

The favorable position of agricultural processing in terms of low direct investment cost per 100 jobs created in the short and long runs has little relevance in attaining state development objectives if there is little potential for national growth in demand, or if Oklahoma is unable to capture increasing shares of the national market. Growth characteristics of agricultural processing given in [10] indicate that it is not a growth industry nationally and that the rural states of the Great Plains region are not capturing increasing shares of the national market. Oklahoma's share of the national market for agricultural processing has remained fairly stable over the past decade.

The general simulation model assumes that Oklahoma's exports grow proportionally as U. S. demand increases. For Oklahoma, the projected increase in agricultural processing wage and salary employment, assuming the 1963 market share, equals 1,417 man-years from 1970 to 1980 [3]. Thus, changes in industry mix for Oklahoma only reflect relative changes in U. S. demand. By increasing its share of the processing of agricultural products, Oklahoma will have a further change in industry mix. The impact of such changes can be viewed by measuring the total employment change for the state over a given time period.

The procedure used to incorporate an increase in Oklahoma's share of agricultural processing required three steps. First, Oklahoma's share of total U. S. production had to be determined for agricultural processing. Second, Oklahoma's share of total U. S. production was assumed to increase by 10 percent in 1970. The increased agricultural processing output resulting from the increased production was assumed exported. Third, exports of agricultural products (livestock and livestock products and crops) were decreased by an amount equal to

[11] The induced consumption and induced capacity effects make up the long-run induced employment effects. Changes in labor productivity also affect the number of jobs created in the long run.

the additional input requirements resulting from the increased agricultural processing. This step assumed that raw materials needed by the processing sector would be obtained from the agricultural sectors by decreasing exports without causing a further increase in primary production.

Data in Row 1 of Table 4 indicate total Oklahoma employment for all sectors if exports grow proportionally as U. S. demand increases. Employment in Oklahoma is projected to increase from 1,020,110 man-years in 1970 to 1,347,645 man-years in 1980. Data in Row 2 (Table 4) indicate the impact on employment if Oklahoma's share of total U. S. agricultural processing employment increased 10 percent in 1970. The impact of the change in industry mix would cause employment in Oklahoma to increase by 4,702 man-years in 1970 and 5,524 man-years in 1980.

The analysis illustrates changes in employment if the industry mix in Oklahoma were altered. Raw materials for the processing plant were assumed obtained from within the state; thus, the secondary impact would occur mainly in the service-type sectors. For increased processing to occur, the rate of return on private investment would have to be comparable to alternative investment opportunities.

Table 4. How Oklahoma's share of U. S. agricultural processing affects total projected employment

	Employment 1970	1980
	----man-years----	
Total Employment if Oklahoma's Exports Grow Proportionally as U. S. Demand Increases	1,020,110	1,347,645
Total Employment if Oklahoma's Share of U. S. Agricultural Processing Increases 10 percent	1,024,812	1,353,169
Net Change	4,702	5,524

References

[1] DOEKSEN, GERALD A., *A Social Accounting System and Simulation Model Projecting Economic Variables and Analyzing the Structure of the Oklahoma Economy*, unpublished Ph.D. thesis, Oklahoma State University, 1971.

[2] ———, AND DEAN F. SCHREINER, *An Analysis of the Capital Structure by Private Sectors in Oklahoma*, Oklahoma Agr. Exp. Sta. Bull. B-694, July 1971.

[3] ———, *A Simulation Model for Oklahoma with Economic Projections from 1963–1980*, Oklahoma Agr. Exp. Sta. Bull. B-693, May 1971.

[4] ———, "Simulating Short, Intermediate, and Long Run Effects of Private Investment on Employment by Industrial Groupings," *J. Regional Sci.*, forthcoming, August 1972.

[5] GOODSTEIN, MARVIN E., "A Note on Urban and Nonurban Employment Growth in the South, 1940–1960," *J. Regional Sci.* 10:397–401, Dec. 1970.

[6] HAREN, CLAUDE C., "Rural Industrial Growth in the 1960's," *Am. J. Agr. Econ.* 52:431–437, Aug. 1970.

[7] LITTLE, CHARLES H., AND GERALD A. DOEKSEN, "Measurement of Leakage by the Use of An Input-Output Model," *J. Farm Econ.* 50:921–934, Nov. 1968.

[8] MAKI, WILBUR R., RICHARD E. SUTTOR, AND JERALD R. BARNARD, *Simulation of Regional Product and Income With Emphasis on Iowa, 1954–1974*, Iowa Agr. & Home Econ. Exp. Sta. Res. Bull. 548, Sept. 1966.

[9] National Planning Association, *State Economic and Demographic Projections*, Regional Economic Projections Series, Report No. 70-R-1, Washington, 1970.

[10] SCHREINER, DEAN F., AND LARKIN WARNER, "Contributions of the U. S. Economy from Industrial Development in the Great Plains," in *Attaining Economic Development: How the Great Plains Can Contribute to the U. S. Economy*, ed., Daniel D. Badger, Great Plains Agr. Council Pub. No. 49, 1970, pp. 143–210.

[11] WADSWORTH, HENRY A., AND JAMES M. CONRAD, "Leakages Reducing Employment and Income Multipliers in Labor-Surplus Rural Areas," *J. Farm Econ.* 47:1197–1202, Dec. 1965.

Communications

TRADITION AND PROTECTIONISM—THE AAEA AND ITS JOURNAL*

Agricultural economists routinely deplore fiat protectionism in trade. Our philosophies and expertise call for comparatively free flowing commerce.

It is therefore something of a paradox when the association for agricultural economists considers turning protectionistic regarding its one merchandisable product, its journal.

Moralizing comes easily to mind: we all are free traders until our own product comes under fire.

At the August 1971 business meeting held in Carbondale it was suggested that the AAEA begin copyrighting the *Journal*. Objections were raised and the proposal was not pressed, but it could be readvanced with perhaps a proviso that individual authors may elect noncopyrighting.

Reason for the proposal is fear that enterprising printers will reproduce the *Journal* or parts of it for a market that might cut into some subscriptions or sale of back issues. The AAEA gets a trickle of income from back issues sold. The economy reprinting might be done abroad.

The principal objection to copyrighting is that it would violate the basic reason for publishing the *Journal*, which is to disseminate information as far and wide as possible. The *Journal* is not intended to to be profitmaking. We say as much in our articles of incorporation. In fact, any evidence to the contrary could jeopardize our tax-free nonprofit status.

Copyrighting has been proposed several times in the past. It has always been rejected and should be again.

But the purpose of this note is not to belabor that issue. Rather, the message is that it is time we shucked moss-coated tradition and changed the method of printing our *Journal*. We can taunt ourselves doubly: (1) We laud technological advance in agriculture but resist it for ourselves; (2) Reproducing our product is attractive because the product is overpriced. The latter strikes an analogy with familiar calls for protectionism.

If enough money can be saved in printing, the occasion for copyrighting the *Journal* vanishes. (Any author, of course, can copyright his own article.)

Put simply, typesetting should be abandoned in favor of photographic reproduction. Typesetting still has a place in printing but is too costly for a publication of only 6,500 copies. Photographic processes have been improved immensely and are coming into ever wider use.

Probably the best arrangement would be to prepare copy for printing at a location near the editor. It should be done on automatic typewriter. An $8\frac{1}{2}\times 11$ page size, two columns, would be most efficient. For further saving, margins could be left unjustified but in view of long-established practice we probably would accept the extra cost of justification. The *Situation* reports of the Economic Research Service are an example of margin-justification by automatic typewriter.

Authors, however, should be required to prepare mathematical notations in final form to save cost and minimize errors. Authors should likewise prepare tables for photographing. However, it might be best first to submit rough drafts for the editor's instructions.

The *Journal* would then be printed from camera-ready copy by offset. Printing costs would not differ greatly from the letterpress now used. The saving, of course, is not in press runs but in avoiding the costly setting of copy in monotype.

Ingenuity in procedure should give a cost lower than European or Eastern printers can quote. If not, an interesting question is raised: are we ideologically proscribed from going abroad for our printing?

A further suggestion for economy is to drop all perishable items from the present *Journal* such as announcements and news notes and put them in the newsletters we receive periodically.

Harold F. Breimyer
University of Missouri

* The most valuable contribution of Kenneth E. Miller toward these notes is gratefully acknowledged.

TRADITION AND PROTECTIONISM—THE AAEA AND ITS JOURNAL: REPLY

The American Agricultural Economics Association has no desire to protect "moss-coated tradition" for its sake, nor does it have any desire to change for the sake of change. The AAEA strives to produce its journal with an acceptable quality and appearance at regular intervals and at the lowest cost. After considering various alternatives, it is believed that our present arrangements fulfill these objectives.

The *Journal* is currently set with monotype and the 7,250 copies are run on letterpress. This relatively small number of copies makes it more expensive to use the offset process than the letterpress because after a suitable first copy is made, photographic plates have to be made for the offset process. And surely, Breimyer does not regard photographic reproduction as being a substitute for typesetting or composition of copy. It is true, however, that the offset press usually runs at a faster rate, but the time and expense of preparing plates would be greater than time lost by using a slower press.

Breimyer suggests that the editor prepare the camera-ready copy on an automatic typewriter. Not knowing what kind of equipment he had in mind, we determined the cost of composition of camera-ready copy for the November 1971 issue by the IBM MT/ST with a composer made by IBM. We were able to determine that 120 actual hours were required to type and prepare camera-ready copy for a 32-page journal, $8\frac{1}{2} \times 11$, justified margins and with no mathematical and statistical notations or data. With a 160-page journal such as the November 1971 issue, the requirement would be 600 hours, and with a conservative 30 percent increase required for the amount of mathematical and statistical materials, the total labor requirement for a camera-ready copy for one issue would be 780 hours. On the assumption that all issues would average to that of the November issue, a yearly labor input for typing and preparation would be 3900 hours, or 2.1 full-time girls. This estimate does not include such factors as training periods due to resignations and the retyping of errors discovered in proofs which may add as much as one half-time equivalent.

The following budgeted operations to compose camera-ready copy via IBM MT/ST are based on situations prevailing at Lexington or Gainesville:

Item	*Yearly Cost*
2 typists @ $7,000	$14,000
1 girl for paste-up and proofing	5,500
2 IBM MT/ST input units @ $281/mo.	6,744
1 IBM MT/ST composing unit @ $365/mo.	4,380
Office supplies	1,200
Office furniture, 5-year dep.	250
Office rental	2,400
Supervisor, professional time, 1½ mos.	3,000
Repros, 50 hours @ $10/hr.	500
Plates, 16 up, 50 plates @ $50	2,500
Total estimated costs:	$40,474

The actual cost of composition, printing, and mailing the November 1971 issue was $9,087.33 of which $4,653.83 was for composition. On the assumption that all issues would average to this issue, the total to be spent in a year for letterpress composition would be $23,269.15. Composition expenditures would be the only costs eliminated by providing a camera-ready copy. This means that to provide a camera-ready copy for five issues, it would cost at least $17,000 more than presently charged by our present printers.

The Printing Department of the University of Kentucky was approached with the idea of preparing camera-ready copy for the *Journal* on the same equipment indicated above. Since this work would exceed the department's available capacity, the acquisition of the above equipment would be required. The department prints journals for other associations, including the *American Bibliography of Agricultural Economics*, but provides no additional services such as wrapping, addressing, mailing, storage, and maintenance of address plates.

There are certain external factors and risks involved in attempting to produce the *Journal* as a "cottage enterprise." First, we would be substituting amateurs for professionals. The present printers have engaged in printing some 130 journals for decades and this is a small fraction of their business. Their knowledge and experience in scientific journal production are unsurpassed by any printing firm. Second, it would be difficult to recruit, train, and manage an office that would shift to a new location every three years with the change of editorship. This situation would not only increase cost but possibly jeopardize the scheduled output of the five issues each year. Third, we know of no qualified professional economists who would consider acting as editor and supervisor of Breimyer's proposed setup.

We explored a number of local commercial plants which we thought would possibly consider preparing a camera-ready copy with a performance guarantee to meet our required schedule. No firm expressed any interest. Perhaps larger firms would be interested, but their quotes would probably be in line with our present costs. The most frequent reason given for not having any interest is that it would require too much of their capacity, possibly 75 to 80 percent, to compose our *Journal*. Moreover, because of personnel risks, they could not guarantee a date of delivery, e.g., foreign printing. This alone would jeopardize the printing schedule and consequently the second class postage permit. Furthermore, upon learning what our present composition rates are, each firm, without exception, indicated that our present rates were lower than what they must charge should they seriously consider the job.

Thus, agricultural economists are not resisting

technological advance in terms of their *Journal*, as suggested by Breimyer. Quite the contrary. The technological "innovation" of composing camera-ready copy via an IBM MT/ST has not been adopted because of its relatively high cost when compared with our present monotype-letterpress method, not to mention an array of noneconomic limitations. Neither is the final product overpriced, as implied by Breimyer in reference to reprint prices. Of the 86 economics journals published with an extensive readership in the United States, only three (*American Economic Review*, *Journal of Economic Literature*, and *The Bell Journal of Economics and Management Science*) give subscribers more output per dollar than the *American Journal of Agricultural Economics* [1, pp. 801–803].

Considering the quality of product, the services rendered, the confidence that the job will be done with expertise and on schedule, we are firmly convinced that the Association is following the best alternative at the present time. We are also aware of the fact that technological and economic conditions do change and we do not intend to let tradition dominate us at any cost.

Irrespective of the method of composition, printing costs have been rising. As an alternative to increased subscription rates, some scientific journals have gone to page charges as a means of generating a source of funds to offset printing cost increases. A page charge policy for the *American Journal of Agricultural Economics* is presently under study by the Board of Directors of the Association.

Our present printers are aware of the financial problems of professional associations. And they have notice that we are constantly searching for acceptable alternatives which will minimize the cost of the *Journal*.

JOHN C. REDMAN
University of Kentucky
LEO POLOPOLUS
University of Florida

Reference

[1] BERG, SANFORD V., "Increasing the Efficiency of the Economics Journal Market," *J. Econ. Lit.* 9:798–813, Sept. 1971.

ALLOCATIVE EFFICIENCY, TRADITIONAL AGRICULTURE, AND RISK: COMMENT*

Our toolkit for the analysis of efficiency received a valuable addition in Dillon and Anderson's recent contribution [1]. To my knowledge, they have for the first time incorporated risk considerations into the appraisal of resource use efficiency. Since this is probably only a beginning in this fruitful direction, it is likely that various questions will be raised, questions that will depend on how the researcher weighs the importance of those influences which Dillon and Anderson abstracted from their analysis. The following remarks are thus a personal choice.

What Dillon and Anderson call "uncertainty" is, in fact, uncertainty about the production function. This uncertainty has two aspects. First, even if the true production function were the same for all farmers for all periods, it is uncertain whether we have estimated the production function correctly. Because of noise in the universe, measurement, and specification errors, the estimated production function will inevitably differ from the true one. Second, there is uncertainty about the production function in the sense that the estimated coefficients are not fixed but are the means of a probability distribution. Using the second moments of this joint distribution is the main contribution of Dillon and Anderson, and it must be regarded as a better approximation of the real world than the present usage of treating estimates of coefficients as fixed. However, it does not seem correct to obtain the probability distribution of the b_i's from a cross-section distribution of all observed firms at one point in time and then to use this distribution for the representative or mean firm. The process which generates the random disturbances for different firms at one point in time seems very different from the process which generates them for one firm (one location, one manager) at different points in time. In essence, this comes back to the old question of the interpretation of the production function for the "average firm"—a firm that does not exist in reality. The production function for the average firm is widely used and has proven its usefulness, even given the abstraction from reality. However, it seems that this drawback gets a heavier weight now that so much more importance is attached to the variances of the estimated coefficients.

The problem inherent in the use of the average production function may be approached in the

* I gratefully acknowledge the help and contribution of Paul E. Belec, who originated some of the thought behind this comment; Dr. J. L. Dillon, who painstakingly reviewed an earlier draft for style and content; Dr. P. A. Yotopoulos for his critical stimulation; and Dr. L. J. Lau for his help on the final draft.

following manner. We want to measure "technical uncertainty," that is, the extent to which the actual coefficients of the production function in a particular year differ from the expected coefficients, assuming that we know the functional form with certainty within the relevant range. The new method does not allow us to distinguish this "technical uncertainty" to the extent to which individual firms operate on production functions different from the mean production function. The estimated "technical uncertainty" will additionally include errors due to errors in measurement and in the model and noise in the universe, where ideally it should be free of these influences. This implies that the "technical uncertainty" will tend to be overestimated.

This difference between what we want to measure and what we actually measure may be the reason why Dillon and Anderson have *not* taken expectations over the constant term in the production function. They may have thought that the variance in this term is essentially an expression of firm differences, assuming the coefficients for the inputs are constant between firms. When their technique is used for one firm with many observations, the dispersion over the constant term should also be taken into account, even though it has no known price or marginal product. The uncertainty in this factor may be as important as that of other factors in generating output uncertainty.

Some of the problems of working with a (geometric) mean firm might be overcome by computing the expected loss for each firm individually while maintaining the assumption of one production function for all firms. This would imply first calculating the optimal input vector for each firm, given the firm-specific budget, and then calculating the expected loss for each firm, using firm-specific actual and optimal inputs instead of geometric means. In order to obtain a single expression for the efficiency of the group of firms in the sample, one can compute the average of the firm-efficiencies. This method thus postpones the averaging process to a later stage.[1]

A completely different question is how important is "technical uncertainty" for the individual farmer? Although it is not a fair comment, I may at least express the opinion that decision behavior with respect to *price uncertainty* seems more relevant for understanding farmers' decisions. In deciding whether the farmers act more "rationally" or whether they allocate their resources efficiently, price uncertainty might well prove more important than technical uncertainty of the type presently under discussion.

It should be noted that the budget constraint, so vital an element in Dillon and Anderson's model, might not be a fair description of the reality. Resource availability is, at least at the margin, in practice often more flexible than a budget constraint assumes. For example, would it not be possible for farmers to borrow money for operating expenses, especially in an essentially long-term model like this? For certain cases an alternative might be to minimize costs under an output constraint. However, I would plead for an evaluation of the reality of the assumption in each specific situation where it is applied.

There is also a mathematical implication in the use of this constraint: the marginal product of an input factor is *not* equal to its price but is equal to $c_i(1+\lambda)$; where c_i is the price of input i and λ the multiplier of the Lagrangian from the constrained maximization equation for profit, given the budget. Finally, one should realize that maximizing profit becomes equal to maximizing output since costs are fixed.

Because Dillon and Anderson did not have the original covariance matrices, they assumed independent coefficients in the production function. Using original data from Yotopoulos [2, 3], I have recomputed Dillon and Anderson's efficiency index, taking account of covariation among the b_i's. The procedure used was to orthogonalize the b-vector and the price vector by premultiplication of the original b-vector by a matrix Z, the matrix of eigenvectors of $(X'X)^{-1}$, X being the data matrix.

To illustrate the effect of using orthogonalized b_i's instead of the original coefficients, a four-variable model was used instead of the six-variable model used by Dillon and Anderson. Their use of education as a sixth variable seems ambiguous; since it is treated as a fixed input, it may as well be left out of the budget. Furthermore, the effect of its omission on the other coefficients was slight. Finally, its price is not known; as has been stated, it is not correct to use its marginal product as its price, and the necessary correction can be computed only when all prices are known. Plant and equipment capital were combined as one factor, mainly to save computer time. The added explanatory power is less than one percentage point difference between R^2's. The regression used, with standard errors in parentheses, was[2]

$$\begin{aligned} Y = \underset{(0.25)}{3.86} &+ \underset{(0.06)}{0.46}X_1 + \underset{(0.0418)}{0.0925}\,X_2 + \underset{(0.0183)}{0.0906}X_3 \\ &+ \underset{(0.0343)}{0.2481}X_4 \quad (R^2 = 0.63) \end{aligned}$$

where X_1 is labor, X_2 land, X_3 plant and equipment capital, and X_4 livestock. All variables are expressed in logarithmic form. The sample size was 430. The covariance matrix was

	X_0	X_1	X_2	X_3	X_4
X_0	0.0619	−0.00564	0.00512	−0.00108	−0.00440
X_1		0.00324	−0.00113	−0.00015	−0.00086
X_2			0.00174	−0.00012	−0.00013
X_3				0.00033	−0.00003
X_4					0.00117

[1] This idea was developed by Belec.

[2] This is essentially regression R_{11} in [2], though it has been recomputed with a different regression program.

Using 29 drs. as the price for labor, 90 drs. for land, and 1.10 drs. for capital, plus the *original* b_i's and p_i's, the opportunity loss is 377 drs., expected loss 400 drs., and the Dillon and Anderson index of inefficiency 0.17 (with $\bar{\pi} = -2{,}331$ drs. and $\bar{\bar{\pi}} = -2{,}709$ drs.). Using the orthogonalized b_i's and p_i's, opportunity loss is $-1{,}355$ drs., expected loss $-1{,}311$ drs., and the index of inefficiency 0.05. Thus, in the present case introducing the intercorrelations between the b_i's decreases the expected loss and also decreases the measure of allocative inefficiency.

A problem arises with the possible negativity of the transformed b_i's and p_i's: in the present case, b_2 and b_4, as well as p_2 and p_4, become negative. This leads to negative coefficients for the input factors X_2 and X_4 and a negative budget. One should realize that the orthogonalization does not lead to better estimates or calculation prices but is merely a manipulation of the estimates and prices. However, negative inputs do seem unrealistic. It might be worthwhile to experiment with the constraint of non-negative input factors.

H. C. MOLSTER
Food Research Institute
Stanford University

References

[1] DILLON, JOHN L., AND J. R. ANDERSON, "Allocative Efficiency, Traditional Agriculture, and Risk," *Am. J. Agr. Econ.* 53:26–32, Feb. 1971.

[2] YOTOPOULOS, PAN A., *Allocative Efficiency in Economic Development*, Research Monograph Series 18, Athens, Center of Planning and Economic Research, 1967.

[3] ———, "On Efficiency of Resource Utilization in Subsistence Agriculture," *Food Res. Inst. Stud.* 8:125–135, 1968.

ALLOCATIVE EFFICIENCY, TRADITIONAL AGRICULTURE, AND RISK: REPLY

Molster suggests two main points. First, examination of allocative efficiency through cross-sectional analysis should not focus only on the average producer, but should, so far as possible, account for the efficiency of individuals in the sample. Second, empirical estimates of expected loss are likely to be biased upwards when covariances among production elasticities are ignored.

We agree that it makes good sense to emphasize the individuality of producers, but we fear it is asking too much of the humble cross-sectional production function that it assist in determining individual efficiency. The conventional cross-sectional production function represents the average input-output relationship and as such cannot adequately apply to each and every member of the sample. Only if it were possible to estimate the production function of each sample member would it be logical to integrate expected losses over the sample space.

In some further work on assessing efficiency in cross-sectional analysis [1], we have found that proper accounting for the covariances among elasticities results in smaller estimates of expected loss. This underscores the importance of adequate statistical reporting. In particular, regression reports should always include the covariance matrix if readers (particularly those of Bayesian ilk) are to be well served.

JOHN L. DILLON AND J. R. ANDERSON
University of New England, Australia

Reference

[1] ANDERSON, J. R., AND JOHN L. DILLON, "On Estimating Allocative Efficiency in Cross-Sectional Analysis of Production," *Australian J. Agr. Econ.* 15:146–150, Dec. 1971.

A SIMULATION STUDY OF POPULATION, EDUCATION, AND INCOME GROWTH IN UGANDA: COMMENT

In their study of population, education, and income growth in Uganda,[1] Foster and Yost [3] made a useful and unique application of simulation techniques. However, they might improve upon their model by employing the equivalent consumer concept and an age-consumption variable. The following paragraphs will explain and document the use of the equivalent consumer and age-consumption variables and relate this concept to the F-Y simulation.

The Equivalent Consumer Concept

The equivalent consumer concept is based on the rather simple proposition that the consumption of

[1] Henceforth referred to as the F-Y study.

goods and services is related to age. To compare the consumption of different populations some index must be employed. In the most common indices, a working adult (age 20–64) is assigned a weight of one. Younger (age 0–19) and older (age 64+) persons are presumed to consume less and carry smaller weights.

The equivalent consumer concept has been employed frequently in economic and demographic research, and has been used to compensate for age differences in international and time-spanning comparisons of income [4, 6, 7]. Also, it has been incorporated into several economic-demographic models, most notably the work of Coale and Hoover [1] quoted in the F-Y study. Other studies employing this concept have been those of Enke [2], McFarland and O'Hara [5], and Zaidan [8].

In economic-demographic models, the equivalent consumer concept is employed by including an age-consumption variable in a two-argument consumption function of the form:

$$C = c_y Y + c_e P_e \tag{1}$$

where

C is total consumption,
Y is income,
c_y is the income coefficient,
P_e is the total population measured in terms of equivalent consumers,
c_e is the equivalent consumer population.

In this form, the amount of consumption changes with a change in the age distribution of the population as well as with a change in income. The amount of investment is affected in the following manner: a change in the rate of fertility will affect the number of equivalent consumers, the number of equivalent consumers will affect the amount of consumption, and the amount of consumption will affect the amount of savings and, hence, investment under equilibrium conditions.

Equivalent Consumers and Foster-Yost Model

The F-Y model could incorporate an age-consumption variable into the existing framework. Figure 1, a slightly altered version of the F-Y flow chart, indicates some changes that could be considered. Instead of a direct relation between community income and education expenditures, an intervening step could be added. Income could be parceled into consumption and savings (with savings = investment) and education expenditures related to total investment rather than total income. Consumption could also be a function of the age distribution of the population, as well as income, with a consumption function of the form stated above. Within this framework, levels of income and education expenditures would reflect more accurately changes in the rate of population growth.

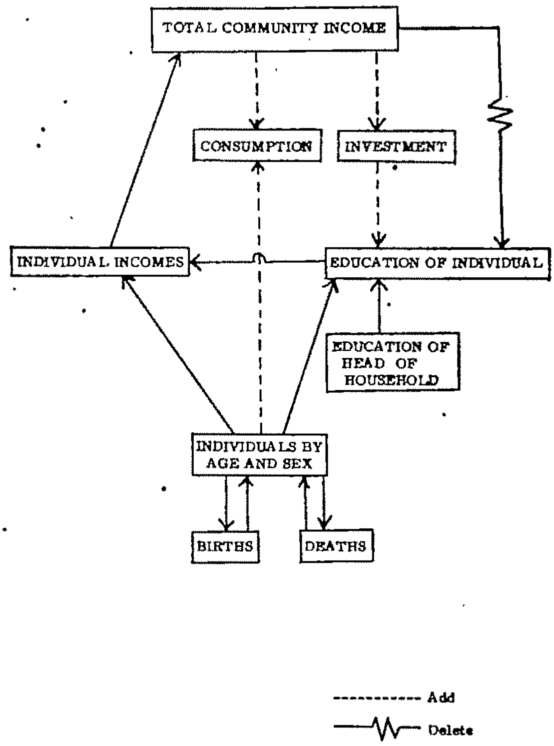

Figure 1. Basic Economic Model

It is doubtful that the direction of the results of the F-Y study would be changed by incorporating an age-consumption variable into the consumption function. Over the 30-year period of the simulation, per capita income and the average age of schooling in the village under study would likely continue to vary inversely with the rate of population growth. However, the magnitude of the differences between per capita income and education with different population growth rates would be anticipated to be lesser or greater, depending on the data used.

By way of illustration it may be useful to contrast the economic activities of an individual from birth, under both the F-Y model and the suggested revision. Under the F-Y model, a newborn individual would enter the economy as neither a producer nor a consumer, but as an additional person in the determination of per capita income. He would not begin to consume until age four and then would consume only education. Under the suggested revision, he would begin at birth to consume some fraction of an adult's consumption of all goods and services.

DOUGLASS G. NORVELL
University of Tampa

References

[1] COALE, ANSLEY J., AND EDGAR M. HOOVER, *Population Growth and Economic Development in Low-Income Countries—A Case Study of India's Prosperity*, Princeton, Princeton University Press, 1958.

[2] ENKE, STEPHEN, "Raising Per Capita Income Through Fewer Births," Santa Barbara, Calif., General Electric, 1968.

[3] FOSTER, PHILLIPS, AND LARRY YOST, "A Simulation Study of Population, Education, and Income Growth in Uganda," *Am. J. Agr. Econ.* 51:576–592, Aug. 1969.

[4] KLEIMAN, E.,. "Age Composition, Size of Households, and the Interpretation of Per Capita Income," *Econ. Develop. & Cult. Chg.* 15:37–58, Oct. 1966.

[5] MCFARLAND, DAVID, AND DON O'HARA, *Turkey: The Effects of Falling Fertility*, Santa Barbara, TEMPO, 1969.

[6] TOUGH, EVELYN G., AND E. L. KIRKPATRICK, "Scales for Measuring the Standard of Living," *J. Am. Stat. Assoc.* 28:55–63, March 1933.

[7] WOODBURY, ROBERT MORSE, "Economic Consumption Scales and Their Uses," *J. Am. Stat. Assoc.* 39:455–468, Dec. 1944.

[8] ZAIDAN, GEORGE, "The Foregone Benefits and Costs of a Prevented Birth: Conceptual Problems and an Application to the U.A.R.," International Bank for Reconstruction and Development, Economics Working Paper No. 11, 1969.

SACRED COWS

Why the cow was selected for apotheosis is obvious to me. The cow was in India the best companion. Not only did she give milk but she also made agriculture possible.

Ghandi

Societies are comprised of a complex array of institutions. Yet, economists who are intent upon developing the Third World do not display much sensitivity to the complex roles played by the local institutions, regarding them as hindrances to the efficient operation of the market. However, these institutions often play important roles in maintaining the stability of the economy. Their abolition might create infinitely more hardships than solutions.

In this paper we consider one such institution, the sacred cow of India, which almost all contemporary economists seem united in condemning. Yet, both Ghandi and the economists are right in their own way. For example, the economists argue that a "reduction in the number of uneconomic animals would contribute greatly to the possibilities of improving the quality and condition of those that remain" [7, p. 19].

On the other hand, it may be rational for the Indians to maintain the large number of scrawny, aged cattle. In fact, one veterinarian who studied African herds observed that the scrawny old beasts were the most resistant to contagious diseases and that they made it possible for the herd to reconstitute itself after the periodic losses caused by rinderpest [5, p. 202]. Furthermore, it is not possible to know when any particular cow will begin lactating or conceiving again, making it difficult to say which cattle must be culled. So, the farmer rations feed among his animals according to their productivity. The small cost involved in maintaining the oldest cattle makes their rejuvenated productivity a windfall for the owner; and if one dies it is also a windfall for the untouchables for whom carrion is a major source of protein [11]. Furthermore, the cattle are most likely to die during times of stress or famine when the malnourished might most need protein. Thus, society invests a portion of its meager surplus of vegetable matter in these cattle during good times so that it can make withdrawals during times of need. If slaughter became commonplace, unproductive cattle would be butchered and their protein would nourish the rich instead of the poor who need it the most. The taboo has a subtle income redistribution effect built into it.

What if the economists are correct that India would be better off if some of its cattle were culled? One economist estimates that if India slaughtered 30 million female cattle, those remaining would be able to convert the same feed supply into more milk, meat, and dung, and the hides would be of superior quality [4]. Which cattle would be slaughtered is a question of great importance since many of the dry and marginal cattle are owned by the poor peasants. If their cattle were slaughtered, could they afford to buy or rent those services supplied by their cattle at almost no cost?

The cow has qualities which enable it to play a unique ecological role, namely, that of manufacturing protein in the form of milk and meat. Its dung provides fertilizer and fuel; the bullock pulls the peasants' plows and carts. What is most remarkable is that the cow can do all of this without consuming any protein [14]. The cow can live off non-edible organic wastes like stalks of rice and wheat and even consume large amounts of paper with favorable effects [1, p. 58]. In short, the cow need not compete with humans for food.

The cow also cycles minerals in its dung, maintaining soil fertility as long as waste products are returned to the fields. (Harris [3, p. 54] suggests that the latter condition is more or less met.) Some writers [6] maintain that crops grown with natural organic fertilizers are superior to those grown with manufactured fertilizers. Others [13] claim that cultivation by bullock-drawn plows is superior to

tractor cultivation. Both of these arguments support the sacred cattle tenet, but neither is essential for our purposes at this moment.

Of course, the peasant could still have the option to use traditional methods if the taboo on cattle slaughter were lifted. Just let the market determine who does what. But, if we accept that point of view, we must face some problems which become apparent when we examine how our own economy manages livestock.

For example, transportation costs make up *half or even more of the final cost of cattle* [9, p. 18]. As a result, livestock producers rely on more concentrated feedstuffs like grain or fish meal as cattle feed. In 1968, for example, Peru and Chile shipped about 700,000 tons of high protein fish products into the United States [8, p. 12], most of which was fed to animals. Moreover, in the United States in the period 1954–56 more than 72 percent of the tonnage of all harvested crops was used for feeding livestock [2]. United States cattle certainly do compete for food with humans.

Even though a few people in the United States cattle industry are beginning to realize that cattle can be fed organic waste products with good results, at the present time it seems more "economical" to most of the industry to leave both dung and organic refuse to build up as solid waste disposal problems. Even if these wastes were fed to the cattle, and the cattle fed to people, human waste would still remain in the American city since it is too bulky to ship back to the farms as fertilizer. With the cattle separated from the farms, farmers often find it cheaper to burn waste products like rice and wheat stalks, thus converting these useful materials into air pollutants. Then, since the soil loses its fertility when its nutrients are shipped to the city, the farmer must buy fertilizers from factories. In the words of one USDA report, "Economic research reveals that it is cheaper to supply fertility from the fertilizer bag, than to meet the costs of hauling manure to the field" [15, p. 10]. These fertilizers can pollute the ground waters and build up harmful residue in crops.

Perhaps the best way of thinking about the last paragraph is in terms of nutrient cycles. Howard Odum has written, "The living forests and reefs have an economy, but instead of money, the currency is made up of materials like phosphorus, carbon, water and the exchange of work services. Plants use the minerals to make food and the consumers send the wastes back to the plant" [12, p. 175]. The sacred cow probably evolved to maintain this mineral economy.

Long ago, when India had fewer people, she could be less careful of the delicate ecological balances. In those days the people ate meat [10, pp. 354–388]. Today, the traditional economy and ecology are strained, possibly near the breaking point. India has too many people and a heritage of centuries of colonialism. It is easy to point to the sacred cattle. Poverty is the fault of the impoverished peasant. He should sell his cow for slaughter. It is that simple.[1]

MICHAEL PERELMAN
Chico State College

[1] Perhaps it is not really that simple. Harris [3] points out that Brazil has a lot of cattle, no taboo, and plenty of hungry people.

References

[1] DANIELS, L. B., AND J. R. CAMPBELL, "Paper—A Cheap Source of Energy for the Cow?" *Hoard's Dairyman* 115:1092, Oct. 1970.

[2] DEGRAFF, HERRELL, *Beef Production and Distribution*, Norman, University of Oklahoma Press, 1960.

[3] HARRIS, MARVIN, "The Cultural Ecology of India's Sacred Cattle," *Current Anthropology* 7:51–59, Feb. 1966.

[4] HESTON, ALAN, "An Approach to the Sacred Cow of India," *Current Anthropology* 12:191–197, April 1971.

[5] HOROWITZ, MICHAEL, "Comment on Heston," *Current Anthropology* 12:201–202, April 1971.

[6] HOWARD *SIR* ALBERT, *An Agricultural Testament*, New York, Oxford University Press, 1943.

[7] KARDEL, HANS, *Community Development in Agriculture: Mysore State*, Washington, International Co-operation Administration, 1959.

[8] LAPPE, FRANCIS MOORE, *Diet for a Small Planet*, New York, Ballentine, 1971.

[9] MEINHARDT, PAUL, "Cattle as an Economic Base for an Ecological Loop, Using Only Organic Wastes It May Be Possible to Produce an Abundance of Beef Without Using Human Food Stuffs," *Feedstuffs* 43:18–20, July 3, 1971.

[10] MITRA, RAJENDRALALA, *Indo-Aryans*, London, Edward Stanford, 1881.

[11] NAIR, KUSUM, *Blossoms in the Dust; the Human Element in Indian Development*, London, G. Duckworth, 1961.

[12] ODUM, HOWARD T., *Environment, Power, and Society*, New York, John Wiley & Sons, Inc., 1971.

[13] SHARMA, OM PRAKASH, "Bullock Plough vs. Tractor," in *The Cow in Our Economy*, eds., J. C. Kumarappa *et al.*, Varanasi, Bhargva Bhushan Press, 1957, pp. 18–20.

[14] VIRTANEN, ARTTHRI I., "Milk Production of Cows on Protein Free Food," *Science* 153:1503–1504, Sept. 30, 1966.

[15] WADLEIGH, CECIL H., *Wastes in Relation to Agriculture and Forestry*, USDA Miscell. Pub. No. 1065, March 1968.

POSITIVISTIC MEASURES OF AGGREGATE SUPPLY ELASTICITIES: SOME NEW APPROACHES—REJOINDER

Tweeten and Quance have chosen to ignore almost completely the main points of my comment [1] in their reply [3] and have concentrated on using a set of data and empirical results to refute my criticisms. A sample of data (especially with all the hazards of aggregate time series) does not by itself prove a thing with respect to statistical bias resulting from specification error or any other causes. If things were as simple as the reply of Tweeten and Quance suggests, the need for mathematical statistics and Monte Carlo studies of statistical estimators would be greatly reduced; statistical estimators could be evaluated on the basis of their performance on a single sample. Unfortunately, the problem is not that easy.

The bias associated with using a function of the contemporaneous dependent variable on the right-hand side of a regression equation was explained in my comment [1, p. 674] and will not be repeated here since Tweeten and Quance apparently accepted that proposition. But they claim specification bias resulting from an alternative form of the supply equation is more serious than the aforementioned bias. Let us examine their specific model of the supply equation and the assumptions which were used.

The input demand equation is specified as

$$X_t = \alpha R_{t-1}{}^{\beta} S_t{}^{\gamma} u_t, \tag{1}$$

where X is aggregate input, R is the ratio of prices received to prices paid by farmers, S is beginning year stock of productive assets, and u is a multiplicative error; while α, β, and γ are unknown parameters. Aggregate output is denoted by O, and T is defined as the ratio of output to input, i.e., $T = O/X$. Multiplication of (1) by T_t yields

$$O_t = \alpha R_{t-1}{}^{\beta} S_t{}^{\gamma}(O_t/Y_t)u_t. \tag{2}$$

Tweeten and Quance said that "since empirical data provide no statistical evidence that T is a function of R, the response of output to price can be found from (1) simply by multiplying X by T" [3, p. 675], which is equation (2) above. Nothing was said about a functional relationship between T and S which is also critical to their "simple" derivation of the response of output to price.

Since Tweeten and Quance found no empirical evidence for a relationship between O_t/X_t and R_{t-1}, what would be a relationship between O_t and X_t which is consistent with this empirical evidence and also equation (1) for X_t? Inspection of (1) makes it clear that the relationship between O_t and X_t would have to be

$$O_t/X_t = f(S_t, u_t)$$

or

$$O_t = f(S_t, u_t)X_t,$$

where $f(s, u)$ is any general function. Likewise, if O_t/X_t is not functionally related to either R_{t-1} or S_t as must be true for Tweeten and Quance to use their equation (1″) logically [3, p. 675] as a derivation from (1), then,

$$O_t/X_t = f(u_t)$$

or

$$O_t = f(u_t)X_t = v_t X_t,$$

where v_t is a random variable. The above implies that mean aggregate output is proportional to aggregate input. What happened to the law of diminishing marginal returns?

Although the above relationships should be obvious, they are formalized to pacify any skeptics. Only the latter case is analyzed since the argument used by Tweeten and Quance in going from the input equation (1) to the output equation (2) requires that O_t/X_t be functionally independent of both R_{t-1} and S_t. Incidentally, this is a stronger condition than that the statistical correlation between O_t/X_t and each R_{t-1} and S_t be insignificant at some arbitrary level.

Theorem. The two assumptions,

(a) $X_t = \alpha R_{t-1}{}^{\beta} S_t{}^{\gamma} u_t$ and

(b) O_t/X_t is functionally independent of both R_{t-1} and S_t, imply that output must be of the form

$$O_t = R_{t-1}{}^{\beta} S_t{}^{\gamma} h(u_t). \tag{3}$$

Proof. First note that output in general is some function, say $\phi(R_{t-1}, S_t, u_t)$, and there is no loss in generality if we write

$$O_t = \phi(R_{t-1}, S_t, u_t) = g(R_{t-1}, S_t, u_t)R_{t-1}{}^{\beta} S_t{}^{\gamma}. \tag{4}$$

That is, for any ϕ there is always a g such that the above equality holds; this is particularly clear since the multiplicative factor on g is positive under any practical situation.

Using (4) as a general relationship for output and assumption (a) as an expression for input,

$$\begin{aligned} O_t/X_t &= g(R_{t-1}, S_t, u_t)R_{t-1}{}^{\beta} S_t{}^{\gamma}/\alpha R_{t-1} S_t{}^{\gamma} u_t \\ &= g(R_{t-1}, S_t, u_t)/\alpha u_t, \end{aligned}$$

which implies that assumption (b) can be met only if

$$g(R_{t-1}, S_t, u_t) = h(u_t). \tag{5}$$

But (5) in conjunction with (4) implies (3) and the proof is complete.

Using (3) and assumption (a),

$$O_t/X_t = h(u_t)/\alpha u_t = f(u_t)$$

and thus,

$$O_t = f(u_t)X_t = v_t X_t \tag{6}$$

where v_t is a random variable which is some general function of the error terms. And as noted earlier, it follows from (6) that mean aggregate output is proportional to aggregate input—a suspicious result, to say the least.

Although the above inconsistency is suspicious, my primary criticism of Tweeten and Quance is

their insistence on using a function of the contemporaneous dependent variable as an independent variable in their regressions. The statistical implications are, as stated before, biased estimators of the parameters α, β, and γ (the estimators are not even consistent); but also, the distribution theory applied to obtain measures of statistical reliability is violated seriously since the residual of the regression will be highly correlated with an independent variable. Therefore, standard errors and t-statistics lose their validity.

The logical inconsistency of trying to measure the mean functional relationship between output and other variables without removing output from the function involving the other variables is completely ludicrous. The latest equation of Tweeten and Quance illustrates the point well. Their equation (1'') [3, p. 675] when converted to logs is

$$\log O_t = \log\alpha + \beta\log R_{t-1} + \gamma\log S_t + \delta\log(O_t/X_t) + \log u_t. \tag{7}$$

Using elementary properties of logarithms, we can write (7) as

$$\log O_t = \log\alpha + \beta\log R_{t-1} + \gamma\log S_t + \delta\log O_t - \delta\log X_t + \log u_t. \tag{8}$$

If it were not for the constraint that the coefficient on $\log O_t$ had to equal the negative of that on $\log X_t$, a least squares fit would yield a coefficient of unity on $\log O_t$ and zero for the other variables. Since exactly the same mathematical form is implied if $\delta\log O_t$ is transposed to the left-hand side of (8), why not use

$$\log O_t = \frac{1}{1-\delta}[\log\alpha + \beta\log R_{t-1} + \gamma\log S_t - \delta\log X_t] + \frac{1}{1-\delta}\log u_t \tag{9}$$

as the regression equation to be fitted?[1] The only problem is if $\delta = 1$ *a priori*; and if it does, only equation (1) needs to be estimated. The *a priori* specification of $\delta = 1$ was shown earlier to imply that mean aggregate output is proportional to aggregate input if the model is internally consistent. Inspection of (8) shows that when $\delta = 1$, $\log O_t$ on each side of the equality cancels, and the remaining terms are merely the logarithmic transformation of (1).

[1] The actual regression would simply be linear in logs for the independent variables given in (9) and the dependent variable, $\log O_t$. If δ is of particular interest, it would be identifiable as the negative of the coefficient on $\log X_t$. Likewise, estimates of the parameters α, β, and γ could also be derived through simple equations in the coefficients from the fitted regression equation and the implied coefficients such as $(\log\alpha)/(1-\delta)$, $\beta/(1-\delta)$, and $\gamma/(1-\delta)$ from (9). The implied division of the residual term by $(1-\delta)$ in (9) is of no consequence. Only approximate standard errors could be obtained for estimators of the separate parameters α, β, γ, and δ. It does not seem very likely to me that we would be much interested in the individual parameters of (9), but instead, parameters associated with the actual coefficients of the linear regression would be of primary concern.

Tweeten and Quance [3] apparently inferred that my criticisms of using O_t/X_t as an independent variable meant that I proposed deleting X_t as an independent variable in any form. Actually, I had no alternative model in mind and only wanted to point out the problems associated with using O_t/X_t. If, and I emphasize *if*, (7) is *the model* to use in an aggregate supply analysis, then (9) is the regression equation that should be fitted to the sample data.

If in the process of formulating a research problem, an equation evolves with the dependent variable on both sides of the equality, the logical thing to do is obtain an explicit solution for the dependent variable as a function of the independent variables. It is, of course, possible that an explicit solution is not possible, and approximations would have to be made to the original equation. An additive relationship comparable to Tweeten and Quance's equation (1'') [3, p. 675] causes no such problem:

$$O_t = \alpha + \beta R_{t-1} + \gamma S_t + \delta(O_t/X_t). \tag{10}$$

Rearranging terms, factoring out O_t, and solving yields

$$O_t = \frac{X_t}{X_t - \delta}[\alpha + \beta R_{t-1} + \gamma S_t]. \tag{11}$$

We do have an estimation problem with (11), since the parameters enter in a nonlinear form. If an additive error term is assumed, nonlinear least squares could be used to derive statistical estimates of the parameters.

Let it be clear that I am not proposing (10), and consequently (11), as a supply function, nor am I particularly supporting (7), and consequently (9), as the most logical approach. My concern is with the statistical methodology used and logical consistency of the analysis done by Tweeten and Quance in [2] and [3]. The point they make in [3], regarding the importance of an input demand equation as a step in estimation of aggregate supply, is well taken. Future research could benefit greatly by giving adequate consideration to the aggregate input demand function.

OSCAR R. BURT
Montana State University

References

[1] BURT, OSCAR R., "Positivistic Measures of Aggregate Supply Elasticities: Some New Approaches: Comment," *Am. J. Agr. Econ.* 53:674–675, Nov. 1971.

[2] TWEETEN, LUTHER G., AND LEROY QUANCE, "Positivistic Measures of Aggregate Supply Elasticities: Some New Approaches," *Am. J. Agr. Econ.* 51:342–352, May 1969.

[3] ———, "On Statistical Intolerance in Supply Analysis," *Am. J. Agr. Econ.* 53:675–677, Nov. 1971.

POSITIVISTIC MEASURES OF AGGREGATE SUPPLY ELASTICITIES: SOME NEW APPROACHES—A FURTHER REPLY*

To quantify or not to quantify, herein lies the dilemma. To quantify is to suffer the slings and arrows of those who cite the inevitable shortcomings of any estimate. Not to quantify is to suffer egregious misjudgments of the impact of policies on the economy. Quantify, we must. But in addition to the use of mathematical statistics and Monte Carlo methods called for by Burt, generous use must be made of economic theory, knowledge of the data, and common sense.

Estimational techniques that minimize statistical bias are frequently shunned for good reason. As a general rule, shortcomings of the data place a high premium on simple models. Ordinary least squares are frequently selected over simultaneous equation techniques, although some least squares bias results. Often a distributed lag form with a constant rate of adjustment is selected even though the lagged dependent variable on the right-hand side of the equation is likely to be correlated with the residuals. In nearly all cases, many independent variables believed to have some effect on the dependent variable are omitted from an equation because to include them would cause coefficients to be highly unstable.

Turning to individual points in Burt's comment, we assumed that a 1 percent increase in the ratio of output to input, the productivity index T, would raise output 1 percent, *ceteris paribus*, and that aggregate output is proportional to aggregate input. Burt thereupon queries, "What happened to the law of diminishing returns?" Since we are dealing with aggregates, the issue is constant returns to scale and not diminishing returns. No severe injustice to reality is done by assuming constant returns to scale.

Burt then goes on to state his ". . . primary criticism of Tweeten and Quance is their insistence on using a function of the contemporaneous dependent variable as an independent variable in their regressions," a procedure that is in his words "completely ludicrous." The basis for this position seems to be his equation (8), from which he concludes that, "If it were not for the constraint that the coefficient on log O_t had to equal the negative of that on log X_t, a least squares fit would yield a coefficient of unity on log O_t and zero for the other variables." We stress that forcing the coefficients of log O_t and log X_t to be equal is much more than a trivial constraint—it removes much of the bias associated with estimating a supply equation with output as the dependent variable and gives every indication of providing reasonably adequate measures of β and γ. Omitting T gives nonsense, as apparent below and in Table 1 of our earlier reply [2].

Our presumption that Burt would omit the impact of T rather than tolerate statistical bias was unfair, but perhaps it can be forgiven since failure to account for T has been almost universal in supply analysis. Burt proposes an alternative (9) for (1″) which was fitted to the data:

$$(9)\ \hat{O}_t = -3.90 + \underset{(.1769)}{.01764R_{t-1}} + \underset{(8.2073)}{1.6122S_t} + \underset{(2.8780)}{1.3467X_t}.$$

$$R^2 = .933 \qquad t\text{-values in parentheses}$$

The coefficient of X_t is $-\delta/(1-\delta)$, implying $\delta = 3.8843$. The equation indicates that β and γ are negative. These estimates of β, γ, and δ are unrealistic, and Burt will say that is because the sample is size 1.

We say that the nonsense coefficients are no surprise and that repeated sampling from a population with the same error structure, serial correlation in the variables, and intercorrelated independent variables would produce similar results. One of the problems is that as δ approaches 1, the value we would expect it to take, the coefficient of X_t approaches $-\infty$. Other portents of trouble are more subtle. Reviewing briefly, aggregate output varies from two sources—changes in productivity and changes in aggregate input. Productivity is not sensitive to price, aggregate input is. Productivity has had a strong influence on output through the years and is highly correlated with aggregate output (current or lagged), aggregate input (current or lagged), the stock of productive assets, and a time variable.[1] Thus, failure to include productivity as an independent variable in the supply equation causes large specification bias as the effect of productivity inflates coefficients of X (current or lagged), S, lagged output, or a time variable. So, the unduly large (algebraic value) coefficient on X_t in the above equation was expected. Furthermore, substantial least squares bias is introduced by including two jointly determined variables O_t and X_t in the equation. Use of the ratio of output to input gives less statistical bias because many sources of error common to O_t and X_t cancel in T.

Burt contends he is not particularly supporting functions such as his (9) or (11) and we understand why. Being human, we are tempted to delight in Burt's unintended evidence supporting our proposition that omitting T in the supply equation trades small statistical bias for large specification bias. Being professionals, we realize those who wish to estimate a supply function really would like to know what form to use. We suggest equation (1″) [2, p. 675] as one which gives reasonably reliable

* Journal Article 2477 of the Agricultural Experiment Station, Oklahoma State University, Stillwater.

[1] The correlation between aggregate input and productivity might suggest causality. Our judgment is that increased productivity is caused by investment in education, research, and other nonconventional inputs.

results if the researcher insists on using output as the dependent variable. We do not contend that (1″) is the all-time best possible specification or that future efforts to improve the specification will be fruitless. But we do contend that equations containing T are still the frontrunners among the currently available specifications of aggregate supply. On the other hand, the input-demand equation (1) [2, p. 675] combines a theoretical formulation that does no severe injustice to reality with simplicity (e.g., few variables) suitable for ordinary least squares. We liked input demand equations in our earlier article [1], still did in our reply to Burt [2], and still do.

LUTHER TWEETEN AND LEROY QUANCE
Oklahoma State University and NRED-ERS

References

[1] TWEETEN, LUTHER G., AND C. LEROY QUANCE, "Positivistic Measures of Aggregate Supply Elasticities: Some New Approaches," *Am. J. Agr. Econ.* 51:342–352, May 1969.

[2] ———, "On Statistical Intolerance in Supply Analysis," *Am. J. Agr. Econ.* 53:675–677, Nov. 1971.

QUANTITATIVE TRAINING OF UNDERGRADUATES: COMMENT

In 1948, Leonard Salter criticized agricultural economists for concluding reports of research with recommendations unrelated to and unsupported by the research [2]. That criticism is still relevant.

In a recent issue of this journal, Jones, Lard, and Manderscheid reported interesting and useful results from their study of undergraduate curricula in agricultural economics [1]. They then proceeded to make these recommendations: (1) "... it is suggested that for non-science students more emphasis should be placed on the application of quantitative techniques to problems in agriculture and agribusiness"; (2) "A second curricular suggestion is that student exposure to the use of computer technology should be increased for all agricultural economics majors" [1, p. 107]. Presumably, the recommendations are an outgrowth of the study. The study does provide information that may be considered necessary justification for the recommendations but it is not in any way sufficient.

The recommendations attempt to set educational and curricular norms. The reported research includes not a trace of scientific inquiry regarding appropriate norms. It is purely descriptive of what departments of agricultural economics do.

There appear to be two implicit assumptions or value judgments associated with this article that control its tone and the recommendations made: (1) There should be much more uniformity of curricula among the various departments of agricultural economics, and (2) for all undergraduate students of agricultural economics, more quantitative training is better than existing amounts or less.

It would be very useful if someone would take these two assumptions as hypotheses and subject them to rigorous testing. Such a study would make a concrete contribution to undergraduate education in agricultural economics. But until then these points remain unsupported value judgments.

My own biases favor the view that flexibility and diversity in curricula are desirable. I like to see education tailored to the goals and objectives of individual students. I find a number of career opportunities available to undergraduate majors in agricultural economics for which extensive training in quantitative techniques is neither necessary nor particularly desirable. In short, the information contained in Tables 1 and 2 of the article by Jones, Lard, and Manderscheid may well show that, regarding the amount of quantitative training, the quality of undergraduate education in agricultural economics in the United States is very good.

VERN ELEFSON
University of Wisconsin-River Falls

References

[1] JONES, LONNIE L., CURTIS F. LARD, AND LESTER V. MANDERSCHEID, "Present Status of Quantitative Techniques in Undergraduate Agricultural Economics Programs," *Am. J. Agr. Econ*, 54:102–107, Feb. 1972.

[2] SALTER, LEONARD A., JR., *A Critical Review of Research in Land Economics*, Minneapolis, University of Minnesota Press, 1948.

QUANTITATIVE TRAINING OF UNDERGRADUATES: REPLY

Professor Elefson's primary critical comment [1] on our recent article in this journal [2, p. 102] is that our recommendations were unsupported by the research results and, further, that the "recommendations attempt to set educational and curricular norms."

In the analysis upon which the article was based, the studies by CEANAR, Coats, Kellogg, Tolley and Grubb, and Walker and Padberg served as norms with primary emphasis on the CEANAR studies. All these were footnoted in the article, but elaboration in the text was limited. The interface between norms and survey results was largely deleted from the article in the rewrite requested by the editor in the interest of brevity. We decided that, since the norms had been published elsewhere, the serious reader could refer to these publications in order to ascertain the validity of drawing our conclusions from the norms and the survey. The alternative was to reduce the original content with respect to survey results which, in our opinion, were of greater interest to *Journal* readers.

On at least one point, Professor Elefson apparently misinterprets our recommendation. He interprets our suggestion "that for non-science students more emphasis should be placed on the application of quantitative techniques to problems in agriculture and agribusiness" [2, p. 107] as a recommendation for more quantitative training. This recommendation was related to the finding that for these students in most departments, quantitative techniques courses were limited to basic mathematics and statistics with few, if any, application or interpretative courses. Of course, increasing emphasis on application may require more quantitative training, or it may only require reallocation of existing training.

We agree with Professor Elefson's suggestion that "it would be very useful to . . . subject them to rigorous testing" [1]. We would add two further comments: (1) the suggestion is equally applicable to all aspects of agricultural economics undergraduate curriculum, and (2) to our knowledge, a definitive research methodology capable of providing the "rigorous testing" has not been devised. Hence, the best we can do at present, especially since we are educating for the future and not the past, is to use the best, forward-looking judgment that can be marshalled.

Finally, we are pleased that Professor Elefson saw fit to comment on our article. His point of view is highly relevant and we feel that further dialogue is needed on the agricultural economics undergraduate curriculum.

LONNIE L. JONES
Texas A&M University
LESTER V. MANDERSCHEID
Michigan State University
CURTIS F. LARD
Texas A&M University

References

[1] ELEFSON, VERN, "Quantitative Training of Undergraduates: Comment," *Am. J. Agr. Econ.*, this issue.
[2] JONES, LONNIE L., CURTIS F. LARD, AND LESTER V. MANDERSCHEID, "Present Status of Quantitative Techniques in Undergraduate Agricultural Economics Programs," *Am. J. Agr. Econ.* 54:102–107, Feb. 1972.

ON THE EVALUATION OF DEPARTMENTS OF AGRICULTURAL ECONOMICS: COMMENT

The Jones-Lard-Manderscheid article [2, p. 102] in the February 1972 issue of this journal was probably quite revealing to many members of our profession. It dealt with a topic and subsequent trend in our profession which is condemned by some and lauded by others. In this relatively simple study a marvelously easy and direct method of evaluating departments of agricultural economics has been revealed.

No longer need we be concerned with measuring the quality of students coming out of each department; no longer need we be concerned with the extent of the education being obtained by students in the various departments; in fact, we will no longer have to trouble ourselves with whether we are producing educated, enlightened citizens. By using this new method we merely have to count . . . 1, 2, 3. To determine the quality of a department, just count the number of quantitative technique courses being offered. It should be quite easy for the profession to adopt this measure since many of us subliminally use it now. Whether evaluating departments or individuals, more quantitative courses are always preferred to less.

But before wholehearted acceptance of this measure can be accomplished, certain problems must be worked out. One inconsistency that exists is demonstrated by Jones *et al.* To quote them, "An understanding of these methods will be essential for future agricultural managers if they are to use research from public institutions effectively and deal with increasingly technical problems in their own occupations" [2, p. 107]. Yet earlier in the article they indicate that 10 departments have eliminated technical agri-

culture courses to make room for quantitative technique courses. How can future managers cope with increasingly technical problems in their own occupations when the technical agriculture courses that might have prepared them for these problems have been removed from the curriculum? How well prepared is the young feedlot manager who, although well versed in quantitative techniques, has had no courses in nutrition or physiology? It would seem now we have an individual who understands the techniques; he just does not understand the problem to which it is to be applied.

What about our responsibility to contribute well-informed and enlightened public citizens? The Jones *et al.* study indicates that nine departments reduced the number of electives taken by their undergraduates. If this trend continues we will negate any social responsibilities we may have had. But, a person should not be concerned with the plethora of political, social, and philosophical problems existing today; as long as he knows his techniques, he will survive. After all, in this the age of the technocrat there is little need or use for erudition.

Another problem that needs to be considered is the proper blend of economics (and related topics) and quantitative technique courses. We all acknowledge that economists need tools to apply their trade, and the various quantitative techniques are those tools. But as techniques are the tools, so economic theory and principles are the bag in which to carry them. Yet we find that three departments have discontinued other agricultural economics courses to make room for quantitative techniques courses [2, p. 106]. A continuing trend of this type will surely lead to the "have technique, will travel" philosophy addressed by William Martin [4]. Quantitative techniques are merely one means to an end; we must guard against the means becoming the end itself. Perhaps it is much simpler for economists to be freed from the nebulous and useless topics of theory and principles so that they can "narrow in" on something tangible and useful as techniques. A trend in this direction would certainly benefit those departments contemplating name changes. They could be referred to as Departments of Economic Engineering, a title with a very austere ring which also removes the agricultural stigma that concerns some of us.

One may wonder why we continue narrowing our curriculum in light of Coats' [1] and Kellogg's [3] rather emphatic statements that the education of agricultural economists must be rather broad in nature. Coats [1, p. 1601] goes further by saying, "The fourth area, and one which we feel offers great room for improvement, is the area of human relations. The economist can render his greatest service to his company only if he knows how to convey his message . . . his knowledge is of little value if he is unable to get his message across effectively." Yet I have never taken nor even heard of a quantitative techniques course that addresses itself to the human aspects of anything. Certainly, the diminution of electives in an undergraduate curriculum will retard one's knowledge of human relations and communication. Might not a course in group psychology or communications be more valuable to the undergraduate prospective manager than a higher order math course?

Traditionally, the educational structure has been pyramidal in shape. Undergraduates received a fairly broad, rounded education. Masters students narrowed their educational interests to a fairly specified field, while doctoral candidates concentrate on a still narrower (in some instances, microscopic) area. But the new trend appears to have streamlined the archaic structure. Rather than a pyramid, the base has been narrowed, reshaped into a straight line structure not unlike railroad tracks passing through a tunnel.

Once these minor problems are overcome, however, we will have a foolproof method for evaluating agricultural economics departments. This method of measurement would surely result in a race quite like the horsepower race of the automotive manufacturers. Nobody really knows why we need more horsepower in our cars, but it sure is a lot of fun watching them being packed under the hood. However, the logical outcome of this numbers race has a very perplexing conclusion. As departments vie for the Number One position, each by adding one more quantitative techniques course and dropping other courses to make room, eventually the "best" Department of Agricultural Economics will be the one that teaches mathematics, statistics, and operations research exclusively!

DAVID B. NARRIE
Virginia Polytechnic Institute and State University

References

1] COATS, NORMAN, "Appraisal of the Current Training of Economists for Positions in Industries Serving Agriculture," *J. Farm Econ.* 48:160–1903, Dec. 1966.

[2] JONES, LONNIE L., CURTIS F. LARD, AND LESTER V. MANDERSCHEID, "Present Status of Quantitative Techniques in Undergraduate Agricultural Economics Programs," *Am. J. Agr. Econ.* 54:102–107, Feb. 1972.

[3] KELLOGG, LESTER S., "Training of Economists for Positions in Industries Serving Agriculture," *J. Farm Econ.* 48:1595–1599, Dec. 1966.

[4] MARTIN, WILLIAM E., "More Sophisticated Tools for Less Important Problems: The History of Range Improvement Research: A Comment," *Am. J. Agr. Econ.* 54:132–134, Feb. 1972.

ON THE EVALUATION OF DEPARTMENTS OF AGRICULTURAL ECONOMICS: REPLY

Narrie's statement is composed chiefly of his personal opinions on revealed trends in departments of agricultural economics rather than his comments on our article [2, p. 102]. Nevertheless, he adopts our article as a vehicle for expressing his opinions. Moreover, he attempts to use the article for a purpose other than for which it was intended. He states that "quality" of departments may be determined by counting the number of quantitative techniques courses being offered. We strongly disagree with this naive method. We made no attempt to evaluate the "quality" of departments. Our descriptive study was intended to elicit what presently exists in quantitative training for undergraduate agricultural economics majors and, based on norms recommended by CEANAR [1], to draw some conclusions and recommendations for change. Our analysis, findings, and recommendations were limited to quantitative training in undergraduate curricula. In evaluating the quality of instruction in agricultural economics departments, one would need to consider the total educational experience involving both qualitative and quantitative aspects of that total.

Since we do not share Narrie's penchant for evaluating education (or departments) by mere counting rules, we cannot accept his condemnation of those departments that reduced electives. By what logic does he assume that reduction of free electives implies reduction in "one's knowledge of human relations and communication" [3]? Certainly the introduction of a "human relations" or "communications" requirement might reduce electives! Furthermore, we ask if an ability to communicate quantitatively is part of a communications ability?

We regret Narrie's misunderstanding of our statements [2, p. 107] regarding interpretation of basic techniques to lead to "meaningful problem-solving." To equate that point of view with the "have technique, will travel" philosophy is surely unsound.

Finally, we share Narrie's concern for undergraduate education and for the pyramidal structure of the curriculum. But, can anyone seriously question the relevance of adequate quantitative training for any liberally educated person living in the 20th century? We think not. Thus, the argument reduces to questions of appropriate content and amount of that quantitative training. On these questions we have offered our recommendations for direction of both content and amount. What are Narrie's recommendations?

Determining appropriate quantitative training is an element of a broader problem of general curricula planning to meet needs of students with varied backgrounds and interests, as well as the needs of agriculture and agribusiness industries that serve as employers of most of our graduates. Concern for this problem and others was expressed by a number of respondents to our questionnaire. This concern was the basis for our last two recommendations [2, p. 107] that were directed toward improving communications and an exchange of ideas within the association on problems of curricula planning and other matters in undergraduate education.

LONNIE L. JONES
Texas A&M University
LESTER V. MANDERSCHEID
Michigan State University
CURTIS F. LARD
Texas A&M University

References

[1] Commission on Education in Agriculture and Natural Resources, "Undergraduate Education in the Physical Sciences and Mathematics for Students in Agriculture and Natural Resources," Washington, D. C., National Academy of Sciences—National Research Council, 1970.

[2] JONES, LONNIE L., CURTIS F. LARD, AND LESTER V. MANDERSCHEID, "Present Status of Quantitative Techniques in Undergraduate Agricultural Economics Programs," *Am. J. Agr. Econ.* 54:102–107, Feb. 1972.

[3] NARRIE, DAVID. B., "On the Evaluation of Departments of Agricultural Economics," *Am. J. Agr. Econ.*, this issue.

ECONOMIC AND POLICY IMPLICATIONS OF POLLUTION FROM AGRICULTURAL CHEMICALS: COMMENT

In a recent communication, Farris and Sprott [1] stated, "Farm programs based on acreage allotments have aggravated the pollution problem; a different approach to supply control is needed to reduce the incentive to substitute chemicals for land." While their statement may be true for some specific chemicals, it is by no means clear that acreage allotments have increased the *total* pollution from crop production or even the pollution from other specific chemicals.

For crops such as corn where acreage allotments and price support programs have held product prices higher than they would otherwise be, nitrogen fertilization rates have increased in response to the favor-

able product-nitrogen price ratio. But the rapid drop in nitrogen prices has been responsible for much of the increase in application rates. Moderately lower crop prices probably would not have resulted in substantially lower rates of nitrogen use. However, if current levels of corn production were grown on more acres with lower yields, the total amount of fertilizer nitrogen required would be smaller, and less excess nitrogen would be lost to the environment. In addition, the nitrogen lost to stream water might be spread over a wider area or at least be somewhat less concentrated in streams draining the most productive agricultural land.

Whether a market quota system would actually result in the substitution of land for chemicals compared to an acreage allotment program is not certain. Farmers may find that the way to minimize cost for a given level of output is to apply relatively large amounts of chemicals on fewer acres rather than to incur the variable costs for items such as gasoline, machine repairs, and seed necessary to operate the additional acres. Any reduction in chemical use is more likely to be due to the production of less total product under a quota system than to the substitution of land for chemicals if the same amount of product was produced under each of the two systems. Thus, if we are really interested in reducing pollution from agricultural production, we should cut production to that amount required to satisfy domestic demand and eliminate exports. Few economists would recommend such a policy.

From a broader perspective, the pollution situation as related to farm programs is probably the reverse of that postulated by Farris and Sprott. Phosphorus is one of the chemicals most often implicated as responsible for lowering water quality. Phosphorus in stream water draining farm land varies little, if at all, with rate of phosphorus fertilization but does vary markedly with the amount of soil erosion [2, 3]. Thus, when nitrogen, phosphorus, and other chemicals are substituted for land in crop production, the total amount of eroded soil and, thus, phosphorus, lost to stream water is almost certainly reduced due to less crop land being exposed to erosion. In addition, to the extent that hilly, erosive soil is idled and production concentrated on more level soils, the percentage of reduction in soil erosion (and phosphorus loss) is likely to be greater than the percentage of reduction in land use. If phosphorus is the "critical" or "limiting" element in the growth of algae and other nuisance aquatic plants, then farm programs which have reduced crop acreages probably have *improved* water quality even though the amount of nitrogen lost to stream water may have increased as a result of these same programs.

Higher crop prices resulting from government farm programs undoubtedly have led to a faster rate of adoption of pesticides than otherwise would have occurred, particularly when farmers are operating under acreage allotments. But the basic reason for the adoption of this technology was that it became available at reasonable prices. Its use would have been profitable at lower product prices than actually existed. Application rate per acre is typically the amount that will control the insects or weeds and varies little with expected crop price or yield. This may imply that farmers are not rational decision makers, but a more plausible explanation is that the shapes of the production functions related to the various pesticides and the prices of many pesticides are such that economic analysis would confirm that farmers' decisions are correct. Unlike the case of fertilizer, economists know little about the shapes of the production functions for pesticides. I suspect that the marginal product of at least some pesticides is rather constant and then abruptly drops to zero. For example, weed control chemicals applied to corn may result in rather large increases in yield until enough is applied to kill all the weeds, after which no additional yield increase occurs. When the cost savings from reduction or elimination of cultivation are also considered, then even rather large changes in product price would not influence the amount of weed control chemicals applied. With the hypothesized shape of the pesticide production function, the marginal value product at the "recommended" levels of application frequently is well in excess of the marginal factor cost of the pesticide. Certainly there are situations where a "market quota with a two-price system, would reduce the incentive to apply 'insurance applications' that sometimes exceed the economic optimum," [1], but I believe this is the exception rather than the rule. Now that farmers are aware of the yield increasing powers of pesticides and if the marginal value product far exceeds the marginal factor cost as I suggest, the application rate or number of acres treated is not likely to be decreased much by a market quota system or lower prices. In fact, for many crops, since the pesticide application rate tends to be (and, in fact, is) a fixed amount per acre, the total amount of pesticide used to produce a given quantity of crop on more acres if, say, nitrogen fertilizer rates were reduced, is more likely to increase than decrease.

The above discussion is not an argument for continuing government farm programs in their present forms. There are good economic reasons for changes in our current farm programs. But, it is not at all clear that the substitution of market quotas for acreage allotments would reduce the *total* amount of pollution resulting from crop production, nor is it clear that pollution from each specific chemical, such as certain pesticides, would necessarily be reduced by such a change in farm programs. In fact, there is good reason to believe that the most likely result of such changes is the opposite of that put forth by Farris and Sprott.

GEORGE L. CASLER
Cornell University

References

[1] FARRIS, D. E., AND J. M. SPROTT, "Economic and Policy Implications of Pollution from Agricultural Chemicals," *Am. J. Agr. Econ.* 53:661–662, Nov. 1971.

[2] JACOBS, JAMES J., "Economics of Water Quality Management: Exemplified by Specified Pollutants in Agricultural Runoff," unpublished Ph.D. thesis, Iowa State University, 1972.

[3] OGLESBY, R. T., "Farm Land Runoff," in *Agricultural Wastes: Principles and Guidelines for Practical Solutions*, Proceedings of Cornell University Conference on Agricultural Waste Management, Feb. 1971, pp. 15–20.

ECONOMIC AND POLICY IMPLICATIONS OF POLLUTION FROM AGRICULTURAL CHEMICALS: REPLY

We appreciate the attention Professor Casler [1] gave our Communication [2], but we cannot accept his conclusion summarized in his last paragraph. Granted, for some crops and areas "... it is not at all clear that substitution of market quotas for acreage allotments would reduce *total* pollution resulting from crop production..." because more acreage might be planted. There are many tradeoffs in pollution questions, but even if we could accept this statement it would not necessarily refute our case. "*Total* pollution" is not defined by Professor Casler; we assume it means total polluting chemicals applied in the United States or a region. The problem with most agricultural pollution is the concentration, not so much the total amount of chemicals applied. Our position is that acreage control and price support programs have given producers of "basic" crops (especially cotton—the leading polluter) the incentive to use larger and larger amounts of chemicals per acre, not only to maximize current income but to increase their future allotment base.

A key point apparently overlooked by Casler is that under the existing program the producer faces the same product/chemical price ratio for the last units of higher and higher per-acre yields. With the market quota system we described, once the quota was reached, the extra units would face a sharply reduced product/chemical price ratio. The current program has provided part of the incentive for producers to adopt a complex of practices to achieve maximum yields. These practices include supplemental irrigation and heavy applications of fertilizer coupled with all the weed, insect, and disease chemicals necessary to achieve top yields. For example, some cotton producers in the Mississippi Delta have in the past adopted a schedule of applying insecticide every five days, which has resulted in two to three times more chemical applications than that applied selectively by producers to prevent moderate to heavy infestation.

Lacewell and Masch [5, p. 8] demonstrated that even for a situation where the last unit of output received the same price, the market quota system would have reduced the nitrogen applied by 18 percent and 2,4-D by 3 percent; net income for the area would have increased $1.2 million compared to existing programs. One of the reasons for the change was a switch from irrigated wheat to dryland.

Horne [4, p. 8], making recommendations for control of corn blight in Texas in 1971, stated, "Control with protectant fungicides is never 100 percent, but satisfactory field control can be achieved with proper timing and application techniques. Yield potentials should be in the area of 100 bushels per acre for fungicide application to be most profitable." A higher product price can make the difference in whether a pesticide is used and a difference in the number of applications when it is not a clear-cut case. Casler did not use empirical data to support his argument, and apparently he did not review the references used to support our case. There is no point in repeating the references, but we might remind him that the heavy applications of chemicals common today were triggered in the mid-1950's when acreage controls became quite restrictive and product/chemical price ratios for cotton, tobacco, and peanuts became more attractive. We could add that where the product/chemical price ratios have been less favorable in countries not limiting acres planted, such as Argentina, levels of chemical applications are substantially lower on cotton, tobacco, and corn than in the U. S. [3]. Casler has not convinced us that our statement is incorrect: "A basic change in farm policy from acreage controls to market quotas could either reduce the incentive or slow the rate of increases in the level of application" [2, p. 661].

D. E. FARRIS AND J. M. SPROTT
Texas A&M University

References

[1] CASLER, GEORGE L., "Economic and Policy Implications of Pollution from Agricultural Chemicals: Comment," *Am. J. Agr. Econ.*, this issue.

[2] FARRIS, D. E., AND J. M. SPROTT, "Economic and Policy Implications of Pollution from Agricultural Chemicals," *Am. J. Agr. Econ.* 53:661–662, Nov. 1971.

[3] FIENUP, DARRELL F., *Changes in Argentinian Agricultural Production and Productivity Over the Past 25 Years*, St. Paul, Institute of Agriculture, University of Minnesota, International Agriculture Series 5, Aug. 1966.

[4] HORNE, C. W., *Plant Disease Views and Reviews*, Texas Agr. Ext. Serv. Leaflet, Nov. 16, 1970.

[5] LACEWELL, R. D., AND W. R. MASCH, *Economic Incentives to Reduce Chemicals Used in Commercial Agriculture*, Texas Agr. Exp. Sta. Tech. Article 9606, 1971.

MECHANIZATION AND SOCIAL WELFARE: A BELATED COMMENT*

The November 1970 issue of this Journal contained a most stimulating article by Schmitz and Seckler on "Mechanized Agriculture and Social Welfare: The Case of the Tomato Harvester" [2]. While its merits have been recognized by its selection as the best *Journal* article published in 1970, it has not elicited the communications one might have expected from such a pathbreaking work. Since no one else has yet come forth, I will.

It is traditionally assumed that in a purely competitive economic system, benefits from the adoption of a new agricultural technology accrue at first to the early adopters and then are gradually worn away as more and more growers adopt the practice. In the final analysis, society benefits through a greater quantity or quality of food at lower cost. But Pareto optimum is not necessarily reached in the process; some groups may be disadvantaged.[1]

Schmitz and Seckler pointed out that these groups need to be considered in policy decisions involving technology, and introduce the idea of compensating disadvantaged groups from the economic surplus generated by technological innovation. There would, obviously, be operational difficulties in carrying out such a plan, worthy as it may be. Let me suggest a few considerations which have probably occurred to the authors but which were not raised in their article.

While the direct profit motive was certainly a major factor in encouraging farmers to shift to mechanical tomato harvesters, an indirect push was undoubtedly caused by the increasing difficulty of obtaining labor to pick tomatoes. The bracero program was effectively discontinued in 1964, sharply curtailing the labor supply. Americans are not notably interested in doing stoop labor, and in any case a higher wage is required. Assuming pickers can be found, higher wages mean that the "surplus" between the cost of picking by bracero labor and the cost of mechanical harvesting is reduced.

Still, some surplus will probably accrue to society. Assuming that government can be convinced to pay compensation, which farm workers should be compensated? The farm labor force is far from homogeneous. In the case of the tomato harvester, the most clearly disadvantaged group would appear to be the American migrants who have few or no viable job opportunities elsewhere. But if they are compensated, what about the braceros who did not lose their jobs as a direct result of the harvester (though perhaps they would have in time) but were clearly involved and clearly disadvantaged?[2] Or what about the part-time workers, such as students, some of whom might have preferred unemployment to picking tomatoes?[3] Moreover, farm workers, as the authors acknowledge [2, p. 574, fn. 11], were probably not the only ones to lose. Producers who were not able to use the harvester because of farm size, topography, or lack of credit may well have been placed at a comparative disadvantage.[4] It would take, I fear, a Solomon to sort out all the parties involved and to assess the degree to which they should be compensated.

However, society (that is, government, presumably at the federal level), should make the payment bates over whether entrepreneurial talents made where society benefits. To what degree is this true under conditions of imperfect competition? What if increased returns from the adoption of a technology —because of lack of mobility of resources, political factors, or other reasons—are largely retained by certain farm sectors? This has happened to some new technologies in certain less developed nations. The Western answer might be that this return can be captured through income taxes. Income taxes, however, are not common in the agricultural sectors of many less developed nations and are not likely to be. Getting any privileged group to share its wealth is never an easy task.

The equity and compensation issues raised in the Schmitz-Seckler paper are of real and vital importance, and they deserve further discussion and study. Hopefully, other readers, as well as the authors, will have further contributions to make on the subject.

DANA G. DALRYMPLE
Economic Research Service, USDA

* I have benefited from helpful comments by Kenneth Farrell and Wayne Rasmussen.

[1] Reference here is to absolute rather than relative disadvantage. Dislocations caused by changes in relative advantage are not to be overlooked. In economic terms this might be considered a different level of priority, while this may not be true in political terms.

[2] I must admit to a special, if unfashionable, personal concern with the plight of the bracero who not only lost his job in the U. S. but also faced very limited employment opportunities in Mexico.

[3] Those who have picked tomatoes for extended periods during summer vacations may not find this attitude difficult to understand.

[4] More recently, Schmitz and others [1, p. 790] acknowledged that "in evaluating the welfare effects of a government programme, the welfare differences between poor consumers and wealthy consumers and between poor producers and wealthy producers may be more significant than the difference between producers as a group and consumers as a group."

References

[1] CURRIE, J. M., J. A. MURPHY, AND ANDREW SCHMITZ, "The Concept of Economic Surplus and Its Use in Economic Analysis," *Econ. J.* 81:741–799, Dec. 1971.

[2] SCHMITZ, ANDREW, AND DAVID SECKLER, "Mechanized Agriculture and Social Welfare: The Case of the Tomato Harvester," *Am. J. Agr. Econ.* 52:569–577, Nov. 1970.

CONVERTING NATIONAL SUPPLY AND DEMAND EQUATIONS TO A COMMON CURRENCY FOR INTERNATIONALLY TRADED COMMODITIES

An interregional trade model using price-responsive supply and demand equations was developed by Takayama and Judge [4] and modified for international trade by Bawden [1]. Larson [3] formulated an interregional trade model which can be modified by Bawden's procedures. Larson's iterative procedure has computational advantages over the Takayama and Judge programming method.

International trade models that respond to prices require that the prices be in a common currency. In their communication on estimating national supply and demand equations in a common currency, Bjarnason, McGarry, and Schmitz [2] omit an advantageous method. They presume that the price series must be converted to a common currency *prior to* estimation of supply and demand equations. They are then concerned with whether to convert the price series to a common currency (US$) at yearly exchange rates or to convert the price series to dollars at a base exchange rate. They found that the base exchange rate is better for conversion than the yearly exchange rate.

Another method would be to estimate national supply and demand equations in national currencies and then convert the equations to a common currency by multiplying the price parameter by the assumed exchange rate. For example, British supply and demand for a commodity would respond to a price in British pounds. To convert to dollars, the price parameter in the supply equation and the price parameter in the demand equation are each multiplied by the exchange rate in British pounds per dollar. The price series in national currency may be adjusted for inflation prior to estimating national supply and demand equations.

This method has an advantage over the methods considered by Bjarnason, McGarry, and Schmitz in that it permits consideration of different exchange rate situations in successive runs of the model. With current monetary developments resulting in more flexible exchange rates through wider margins in exchange rate fluctuations, floating, and reform proposals such as crawling pegs, there is a greater need to compare trade under alternative exchange rate situations instead of assuming fixed exchange rates.

DAVID P. ELLIOTT
London School of Economics

References

[1] BAWDEN, D. LEE, "A Spatial Price Equilibrium Model of International Trade," *J. Farm Econ.* 48:862–874, Nov. 1966.

[2] BJARNASON, HAROLD F., MICHAEL J. MCGARRY, AND ANDREW SCHMITZ, "Converting Price Series of Internationally Traded Commodities to a Common Currency Prior to Estimating National Supply and Demand Equations," *Am. J. Agr. Econ.* 51:189–192, Feb. 1969.

[3] LARSON, ARNOLD B., "Spatial Equilibrium for Related Commodities," unpublished paper, University of Hawaii, 1971.

[4] TAKAYAMA, T., AND G. G. JUDGE, "An Intertemporal Price Equilibrium Model," *J. Farm Econ.* 46:477–484, May 1964

Reviews are listed alphabetically by authors.

Reviews

Berger, Samuel R., *Dollar Harvest*, Lexington, D. C. Heath and Company, 1971, xi + 221 pp. ($7.95)

Commentary on large organizations often runs in a deeply negative vein. It may proceed from a perspective critical of the American system in general or one that is critical of a whole class of institutions; or it may proceed from a case study which evaluates an organization more or less on its own terms, as did the thorough Nader study of the Interstate Commerce Commission [1]. The Nader report concluded on the earnest suggestion that the ICC be abolished.

Also in a negative vein is Berger's book on the Farm Bureau. He appropriately calls it an "exposé." It catches the organization coming and going and is calculated to provoke the reader's sense of outrage.

Berger carries off his exposé very successfully by measuring the Farm Bureau unfavorably against the self-image that it presents to the world. In one sense he is justified in using this standard for judgment. As Berger points out, an insurance company that can pass as a farm organization has unfair advantages over its competitors—in tax exemptions, in access to customers, and in using its political influence to obtain a privileged status before the law. A political lobby with great organizational wealth which can avoid being labeled as a "special interest" also has the best of two worlds.

However, it is misleading to suggest that the large gap between self-image and reality is unique to the Farm Bureau. In this reviewer's opinion, Berger damages his credibility by providing a brief but wholly favorable portrayal of other farm organizations and contrasting that picture with the wholly unfavorable picture of the Farm Bureau. He cannot help but know that all large organizations—not just the Farm Bureau—are oligarchic in their structure, even if democratic in form. He must also know that the key to stability and power, for most large interest-group organizations, is to offer clients a variety of benefits among which the representational benefits are usually the least attractive.

In successive chapters, Berger grants to the Farm Bureau each of the roles with which it has been tagged by earlier critics: it is the "favorite" of the cooperative extension services; it is a front group for the Chamber of Commerce and other business groups, a spokesman for big-time corporation farmers, and an instrument of right-wing extremists. But Berger argues that the major influence upon the Farm Bureau is from its own financial structure. He emphasizes that the Farm Bureau is essentially a big business conglomerate, and he makes an original contribution in developing this theme. He describes a multitude of Farm Bureau involvements, principally in insurance but also in oil, mutual funds, tires, shopping centers, and finance companies. National Farm Bureau leaders claim that these enterprises are virtually autonomous, but Berger presents evidence that the Farm Bureau does coordinate these far-flung activities and reaps profits from them. The profits are used for expansion, and Berger is not hesitant to state that the Farm Bureau's business has grown to mighty proportions: ". . . The Farm Bureau business empire is one of the largest commercial conglomerates in the country, with nearly $4 billion in total assets" (p. 71). Berger says most of the Farm Bureau's members are actually customers who are obliged to buy memberships, and he seeks to demonstrate that customer interests are basically at odds with the Farm Bureau's business ambitions.

Berger's antipathy toward the Farm Bureau developed during the time he served as staff member to Congressman Joseph Resnick, (D.-N.Y.). Resnick as a member of the House Committee on Agriculture, had begun to ask embarrassing questions about the Farm Bureau and had been firmly put down by a majority on the committee. According to Berger, the committee acted at the Farm Bureau's insistence. So, Resnick conducted his own hearings on the Farm Bureau and had begun to summarize the findings when he died in 1969.

Berger desired to complete the work of his friend and former employer, as well as to challenge the legitimacy of the Farm Bureau's efforts on vital issues affecting rural America. Berger thinks that the Farm Bureau played a leading role in defeating a number of vital measures (or delaying them beyond the time when they would have been most effective). Some of these measures are listed in the book's for-

word, written by Cesar Chavez, and include federal aid to education, anti-poverty legislation, and efforts to improve the conditions of life, the legal rights, and the bargaining power of farm workers. On issues such as these a majority of the Farm Bureau's customers or members might well agree with the organization's stand—and so might a majority of rural people. Berger does not face the possibility, which would certainly undermine his case, that where the Farm Bureau was most tragically wrong, it was also most representative.

Don F. Hadwiger
Iowa State University

Reference

[1] Fellmeth, Robert C., and others, *The Interstate Commerce Omission, The Public Interest and the ICC; The Ralph Nader Study Group Report on the Interstate Commerce Commission and Transportation*, New York, Grossman Publishers, 1970.

Cowling, Keith, David Metcalf, and A. J. Rayner, *Resource Structure of Agriculture: An Economic Analysis*, Oxford, Pergamon Press, 1970, xiii + 248 pp. ($7.40)

This book is a collection of past efforts by the authors to build econometric models of the factor markets serving agriculture. They have done an outstanding job of collating their individual works and supplementing them with economic theory, interpretation, and relevant policy implications. The book will become a useful reference to many students and researchers concerned with econometric model-building and the economic relationships of the agricultural factor markets.

Specifically, this book examines the resource structure of the agricultural industry in the United Kingdom and attempts to explain its evolution over time. The empirical analysis is focused essentially on the demand and supply relationships for agricultural inputs from the industrial sectors. It is not directly concerned with resources generated in the agricultural sector nor is it concerned with the flow of agricultural output into the industrial sector. There is a separate theoretical chapter which lays the groundwork for later chapters dealing with specific factor markets. This chapter is based primarily on the orthodox profit-maximizing theory of the firm but with consideration for situations of uncertainty and the dynamic problems of adjustment to equilibrium. However, those with little theoretical background in micro-economics will find this chapter neither easy to follow nor the ideal place to learn the theory of the firm. Its main contribution is to lay the foundation for later attempts at building models of specific input markets.

Each of the chapters dealing with a specific input begins with a description of the market and a discussion of the determinants of demand or supply for that particular factor followed by a presentation of a theoretical model and actual empirical estimates for the model. The chapters end with an evaluation of the econometric results obtained. Data for the empirical analyses are from the post-war period supplemented where possible with material from earlier periods. The authors do a particularly good job of describing the rationale followed in developing each econometric model. Students will find this model development process to be quite educational.

The econometric models developed by the authors are all single-equation models estimable by linear regression techniques. Within this constraint, however, the models are all dynamic insofar as using lagged or appropriately time-sequenced variables. The authors proceed under the assumption that any possible correlation between regressors and residuals may be ignored largely because of the recursive structure of agricultural factor markets. In some cases this assumption would be more convincing if results of alternative attempts at specification and estimation were reported. In addition, the specification at times tends to ignore effects of factor substitution possibilities on agricultural input markets. As this analysis stands, it is difficult to move from the description of one factor market to another with any degree of carry-over or to learn much about the interrelatedness of factor markets.

The empirical econometric analyses of markets for labor, farm tractors and other machinery, and chemicals are well developed and form the structure around which the remainder of the book is built. Markets for remaining resources are treated largely in descriptive fashion.

There is a very interesting chapter treating the inputs for research and development, extension and education. It is mainly a description of the growth of these inputs in United Kingdom agriculture over time. The authors raise some interesting hypotheses regarding the importance of research, development, and education in the development and growth of the United Kingdom agriculture. The hypotheses generated in this chapter would provide a good background for studying the value of these factors in other agricultural sectors around the world.

The authors provide a well-developed and interesting treatment of the relationships which exist between short-run elasticities of agricultural supply and the long-run or equilibrium elasticities of supply. This theoretical discussion makes a distinction between the equilibrium input flow of a resource and the actual input flow. Finally, the book deals with implications of public policy toward economic development in agriculture. This part has no empirical background and deals largely with potential policies for affecting national economic development and adjustments in agricultural markets in the United Kingdom.

Since the book deals with factors in agriculture for very long time periods (early 1900's to mid-1960's) in the United Kingdom, it is possible that the results

would be useful to analyzing anticipated changes in developing countries today. The book is well edited and technically correct in nearly every regard. There is a detailed table of contents to this book but no index. The book could not be described as "easy to read." The general syntax makes the book difficult to follow in many places.

Norman K. Whittlesey
Washington State University

Falcon, Walter P., and Gustav F. Papanek, eds., *Development Policy II—The Pakistan Experience,* Cambridge, Harvard University Press, 1971, xiii + 267 pp. ($9.00)

This book consists of eight essays by members of the Harvard Development Advisory Service (DAS) who worked in Pakistan, mainly as advisors to the Planning Commission and Planning Boards, and who exercised great influence in the formulation of economic policies during the Ayub decade.

The first essay by Falcon and Stern gives a good but brief summary of Pakistan's development. The authors could have included an analysis of the role of the DAS members in Pakistan without changing the quality of their analysis but at the same time providing a valuable lesson for their readers.

Stern, in his essay on "Growth, Development and Regional Equity in Pakistan" develops a dynamic linear programming model to analyze the "time phasing characteristics of the development path for the economy as a whole," as well as separately for East and West Pakistan. The model is highly sensitive to assumptions about the ability to "absorb capital" in the two regions of Pakistan. Since no systematic study was made to determine the absorptive capacity of each region and since the government was in a position to change that capacity by careful investments in infrastructure facilities, there is hardly any basis, other than political, for assuming certain magnitudes of absorptive capacities. This in turn determines the characteristics of regional growth patterns. Stern, however, points out the limitations of the model later in the study and presents a few alternative versions. His overall analysis is good.

Hufbauer's essay on West Pakistan's exports is illuminating and informative. He seems mainly interested in discussing different theoretical concepts with empirical references casually made to emphasize theoretical exposition.

Jacoby presents a planning model for an electric power system. However, this model type is more meaningful for relatively developed and stable countries where the extent of growth in demand and supply of energy can be accurately predicted. The predictability of the model depends entirely on demand and supply estimates, and thus, the results are highly vulnerable to major changes in these estimates. For example, political turmoils from 1969 through 1971 completely changed the expected demand and supply of energy in West Pakistan, making the predicted results of the analysis less meaningful.

Robert Repetto, in his essay, "Economic Aspects of Irrigation Project Design in East Pakistan," discusses very ably some of the special problems of irrigation projects design in that region. His analysis of the problems of using the single-lift pumping system (conventional method) in East Pakistan is particularly revealing. His arguments in favor of the double-pumping distribution system appear to be quite convincing since he not only takes into consideration economic aspects but also administrative and organizational feasibilities of such a program. The essay provides deep insight into problems of irrigation design and management as well as institutional and topographical bottlenecks in implementing irrigation projects already developed. This study should serve as a useful guide to planners everywhere.

Falcon and Gotsch, well known for their work on Punjab agriculture, add another essay, "Relative Price Response, Economic Efficiency and Technological Change: A Case Study of Punjab Agriculture." The first part of the study which deals with the acreage and yield response to prices is well done, though the materials presented were widely published by them previously. The second part, dealing mainly with allocation of irrigation water in response to price changes, is interesting but not quite conclusive since the results are based on normative functions.

Thomas begins his essay on "The Rural Public Works Program in East Pakistan" with gloomy details of its geographic and economic conditions. He pictures the introduction of a public works program as the basic hope for East Pakistan's survival. His analysis, especially concerning the evolution and the workings of the program, is good and informative. However, the analysis with respect to the program's achievements could have been more rigorous. His estimates of the program's benefits are too simplistic and do not take into consideration the effect of the program in accentuating income inequalities and creating social and political unrest in the rural areas.

Papanek provides an illuminating discourse on the educational and occupational background and finance of Pakistan's industrial entrepreneurs. A few additional paragraphs explaining the role of the early industrial licensing policy of Pakistan (rather than the vague term of "government incentives") in transforming traders to industrialists would have added to the completeness of the analysis.

The editors should be credited for presenting a wide range of subjects. The book would have been much richer had the editors included essays on causes and pattern of developments of the major sectors of the economies of East and West Pakistan, the role the DAS played in formulating some of the economic policies, and finally, on the effects of such policies on income distribution and employment generation. Exclusion of an essay on the role of DAS

members in Pakistan has deprived the readers of valuable lessons concerning the danger of advocating policies based largely on narrowly defined economic criteria which ignore socio-political realities. Some of the essays in this collection emphasize the methodology more than the empirical facts of Pakistan's economy and as such provide very few lessons to be learned from Pakistan's experiences. The essays in general, however, provide useful methodologies for analysis of growth, and those by Repetto, Thomas, and Papanek in particular provide excellent reading materials.

M. Raquibuz Zaman
Cornell University
Bangladesh Institute of Development Economics

Fishel, Walter L., ed., *Resource Allocation in Agricultural Research*, Minneapolis, University of Minnesota Press, 1971, ix + 391 pp. ($14.00)

This volume is based on papers presented at a symposium held in Minneapolis in February 1969, jointly sponsored by the Minnesota Agricultural Experiment Station and the Cooperative State Research Service of the United States Department of Agriculture. It is divided into five parts, the first of which is an excellent overview by Tichenor and Ruttan labeled "Problems and Issues" which summarizes the papers constituting the remaining part of the book. The remaining four parts, consisting of 18 papers, are entitled "Research and Welfare," "Investments in Research," "Decision-making in Practice," and "Decision-making Experiments." While the last four sections of the volume address discrete areas, there is good continuity on issues throughout the entire book.

One should not interpret the title of this book as being a dogmatic statement of the contents. Nowhere in the book is there a singular, undisputed prescription for resource allocation in agricultural research. The book might better be described as a reaction to contemporary facts of life in research administration; legislative bodies will not finance research on faith alone. They are demanding increasing justification for new and even continued research efforts in terms of the product the research will yield.

This volume represents a broad and incisive discussion of the problems confronted in attempting to meet the increasing demands for ex ante benefit-cost projections in research planning. As is repeatedly pointed out in the papers contained in this volume, this is the proceedings of just one of many such conferences which have been held in recent times. The sheer volume and intensity of the presentations by the many contributors is perhaps ample evidence of the felt or real crisis of confidence which research planning and budgeting face at this time.

One could not present a brief summary of this volume, and this is perhaps one of its merits. The problems of resource allocation in agricultural research (or any other kind of research) are far from being systematically resolved. There is no consensus among the several authors as to whether the system should start at the top of the hierarchy with a broad problem orientation or arise from its base as the summation of the integrated knowledge gained from research. Upon reading the volume, particularly the chapters by Kaldor, Heady, and Fishel, one is made acutely aware of the inherent complexity of research planning. Kaldor adopts a social welfare model in which he asserts that research should be designed to serve social welfare functions prescribed by the representative legislative bodies. He concedes the expertise of research scientists in designing methodologies to fit the social welfare function but believes that research should emanate from expressed needs of society in a broad context. In the last chapter Fishel points out the difficulties in getting administrative concurrence in what are the necessary increments of broad research programs. Heady, in an expansive paper, points out the complexities of research administration from either end, citing subject matter areas which are in fact closely related even though they deal with widely separated types of research that he characterizes as developmental and compensatory.

In addition to these global issues the volume touches on the matter of the scale and type of institution capable of doing productive research, the effectiveness of several federal and university efforts to evaluate and compile management data on research, and, in the case of Puterbaugh's paper on "The Agricultural Research Service," even the difficulties encountered in classifying research for evaluation.

It would be virtually impossible to summarize the entire volume or pass judgment without repeating the theme of each of the lengthy, and in most instances, quite analytical papers. Thus, it is perhaps better to comment on the usefulness of the volume to various readers and the quality of presentation.

One major purpose this volume may serve for both research administrators and research scientists is to give each a better picture of their mutual dilemma. The administrator is under increasing pressure to justify budgets at the state and federal levels. At both levels he is confronted with informational requirements seemingly possible for non-research types of programs where there is at least logical expectation that tangible measures of results can not only be presented but predicted. The research administrator must either begin to present such analytic evidence or in some future time be prepared to state why such evidence cannot be produced. The researcher, on the other hand, is faced with requests from administrators for quantitative evaluation of their work and finds such requests a distraction and an encroachment on the amount of time he can spend actually doing research. It is possible that the bench scientist is to some extent unaware of the pressures on administrators which create these demands. In this

respect the book can be useful to both by presenting a well-balanced perspective. Papers by administrators vividly describe the system requirements to which they have been subjected. Papers by researchers point out the real conceptual difficulties in providing the requested information. In particular, the last paper in the volume by Fishel raises the question of whether budget planning efforts which require ex ante program planning with output quantification can ever be applied to basic research where the product may not become apparent for some time after the product is produced.

In conclusion, I can only say that the book is worthwhile for those interested in the subject matter and is well organized according to the extent of the readers' interest. The initial chapter by Tichenor and Ruttan is an excellent overview and almost a review in itself of the remaining contents. A reading of this first chapter can almost direct the reader to those remaining parts which might be of most interest. In the remaining parts the book proceeds from the more conceptual and basic to the more applied and institutionalized aspects of research resource allocation. To this reviewer the organization seemed strategically designed to permit several getting-off points for those only casually interested in research administration and for those who are searching for all they can find on the subject and might wish to read to the very end.

LINLEY E. JUERS
Economic Research Service, USDA

Greig, W. Smith, *The Economics of Food Processing*, Westport, The AVI Publishing Company, Inc., 1971, xi + 373 pp. ($21.00)

In this book, Greig and his contributors set out to "provide a general overview of some of the more important economic and business problem areas facing the food processing industry." It contains 13 chapters, including a summary and speculations as to the future. Ten of the chapters are by Greig and three by the contributors. The topics covered include: size of the food processing industry, structure of food processing, economies of scale and future plant numbers, regulation of competition in food marketing, measures of growth, markets for food (retail store and food service), changing technological base in food processing, locational changes, cost differences among states, purchasing function, pollution, and vertical integration and/or systems coordination. The book is intended to "provide the businessman and the student with a general understanding of the system . . . (and) . . . a base . . . for individual investigations on specialized problems."

The author has given himself a broad assignment. It is difficult to say whether the breadth of the assignment or other problems are more influential in its lack of success in meeting its goal. The book reads like a collection of seminar papers, even though 10 of the chapters are by a single author.

The chapter by William A. Cromarty, vice president of the Connell Company, on the purchasing function is an instruction manual on how to be a better buyer by an expert on the subject. Since Cromarty considers it is essential for a buyer to anticipate price movements in the products which he is purchasing, it is also a manual on how to be a price forecaster. While this chapter will be helpful to economists in understanding a much neglected and little understood function, it is not an economic analysis of the purchasing function and its impact on the performance of the production and marketing system. For instance, there is no mention of the presence or absence of economies of scale in purchasing. Perhaps we can hope that Cromarty will find enough time to undertake the latter job before too many years go by.

The chapter on pollution and the food processing industry by Edward Willoughby, director of civil engineering of Giffels Associates, Inc., is pure technology. With the multitude of economic issues in the pollution area, a reviewer might be pardoned for yearning for at least a little economics on the topic.

The book is marred by minor errors, for example, referring to the Census of Manufactures as the Census of Business on page 4 and as the Census of Manufacturers on page 3 and most other places throughout the book. A number of eminent economists will find their names misspelled. The corporate income tax rate is said to be 50 percent on page 27 and 48 percent on page 340.

On somewhat more substantive issues, it is said (p. 74) that large firms do not exhibit economies of scale. Evidence cited is that profits as a percent of net worth decline for the largest firms. Since economies of scale refer to declining unit costs, it does not seem very convincing to cite evidence on profits as a percent of net worth. There are a tremendous number of possible reasons why profits as a percent of net worth could decline with firm size even though unit costs were also declining, including the possibility that book profits (which are what one gets from IRS) may differ substantially from profits as defined by an economist. Accounting methods tend to have a considerable impact on the reported profits, particularly insofar as depreciation is concerned. It may be that the reported decline in profits simply reflects the fact that large firms have better taxmen than small firms do.

"The 100 largest U. S. industrial corporations had the same percentage of assets in 1947 as in 1967" (p. 350), according to Greig. According to Scherer, who spent considerable time on this question in his recent book [2], the 100 largest U. S. industrial corporations had 40 percent of all manufacturing assets in 1947 and 51 percent in 1967.

The discussion of economies of scale in advertising (pp. 67–68) follows the conventional wisdom according to the FTC which holds that there are tremendous discounts available to very large firms from

the television networks. Apparently, this was what the network rate cards of the late 1950's and early 1960's showed. But the rate cards covered only one form of television advertising, the purchase of time where the advertiser supplied the program. This form of television advertising was declining rapidly in the late 1950's and by the mid-60's had virtually disappeared. As the casual television viewer is well aware, most evening television programs are now sponsored under what is known as "participating minutes," under which an advertiser may purchase as little as a single minute per week. By 1965, there was no advantage to large purchasers of advertising time on evening television [1].

Alden C. Manchester
Marketing Economics Division, ERS, USDA

References

[1] Blank, David M., "Television Advertising: The Great Discount Illusion, or Tonypandy Revisited," *J. Bus.* 41:10–38, Jan. 1968.

[2] Scherer, F. M., *Industrial Market Structure and Economic Performance,* Chicago, Rand McNally and Company, 1970.

Hicks, George L., and Geoffrey McNicoll, *Trade and Growth in the Philippines: An Open Dual Economy,* Ithaca, Cornell University Press, 1971, xi + 244 pp. ($8.50)

This book represents an important contribution to understanding the process of economic growth in the Philippines. Implications of the analysis are deeply pessimistic and profoundly disturbing with respect to the prospects for rapid economic growth in the last two decades of the century. In the authors' view the Philippines of the future is likely to bear a closer resemblance to Java than to Japan.

The authors examine the historical growth processes in the Philippines with the aid of a new hybrid growth model incorporating relevant features from the (now) traditional dual economy models with the "staple" and vent for surplus models. In their "open dualistic" model the growth of output in the traditional (agricultural) sector is limited by growth of the labor force rather than land. In their judgment the Philippines and most other countries of Southeast Asia are more accurately described as "land surplus" rather than "labor surplus." Within the modern sector it is assumed that the products of extractive industries (plantations, forests, mines) are exported but that exports of the manufacturing sector are not. Both the extractive and manufacturing sectors are relatively capital intensive. The small size of the economy precludes development of a significant capital goods industry. Capital goods imports are dependent on exports of the products of the traditional and extractive sectors. An important source of dualism has been disequilibrium in factor prices. Public policies have resulted in a situation in which the price of capital to the modern sector has been below its scarcity value and the price of labor has been above its opportunity cost. There has been a substantial capital-using bias in the modern sector. Rapid growth of output has been accompanied by relatively modest growth of employment in the modern sector.

The authors' pessimism with respect to the future growth prospects in the Philippines stems from three observations:

—Rapid growth in exports during the last two decades was based largely on exports of products from the extractive industries, principally forest products. The authors conclude that the rate at which existing reserves are being depleted precludes continuation of the extractive industries as a dynamic source of expansion in export earnings.

—There has been almost no productivity growth in the traditional sector. And, except in the case of rice, the technical basis for productivity growth has not yet been established. Even in the case of rice, realization of the potential productivity of the new high-yielding varieties is constrained by limited investment in irrigation. As the Philippines shifts from a "land surplus" to a "labor surplus" economy, the constraints imposed on economic growth by limited productivity growth in the traditional sector will become more severe.

—The modern sector, except for extractive industries, has not yet begun to demonstrate any significant export potential. The modern manufacturing sector has to a large extent been based on consumer goods import substitution. There has been little backward integration toward capital goods but the import component of investment remains high.

There are bright spots as well as weaknesses in the outlook for the Philippine economy. The experience with rice has demonstrated that it is possible for agriculture in the developing countries of the tropics such as the Philippines, with appropriate investment in the establishment of experiment station capacity, to begin to make the transition from a resource-based to a science-based agriculture—even in an economy dominated by small farms. Import substitution policies of the 1950's did permit a substantial shift in the composition of imports—from consumer goods to capital goods. Philippine economic policy has demonstrated that it is possible to transfer income from the agricultural sector and the extractive industries to serve as a basis for industrial expansion. It has not yet demonstrated whether the new manufacturing sector can be transformed into an efficient source of growth or whether it has, in effect, created a new "rentier" class of industrial entrepreneurs and organized workers.

I have one criticism of the book. The authors impose an unnecessary burden on both their analysis and exposition by adopting the empty taxonomy of traditional and modern sectors.

Finally, the book must be regarded as a tribute to the quality of economic analysis in the Philippines over the last decade. The authors depended heavily

on this very substantial literature, much of which has appeared in *The Philippine Economic Review,* and on working papers by members of the University of the Philippines School of Economics.

VERNON W. RUTTAN
University of Minnesota

Hieronymus, Thomas A., *Economics of Futures Trading, for Commercial and Personal Profit,* New York, Commodity Research Bureau, Inc., 1971, xiii + 338 pp. ($12.95)

My appraisal of this book will be in terms of its potential as a college textbook, although Hieronymus also proposes it as a guide for the practitioner. The book opens with a delineation of the present scope of futures trading followed by a description of its organization and mechanics. The present dimensions and recent extensions to new commodities leave little doubt of the importance and viability of the institution, whereas the long time decline (since the 1880's but particularly since the 1920's) in futures trading in cereal grains and cotton (coffee might also be mentioned) reflects chiefly governmental intervention. The organization, procedures, and specialized participants in futures trading differentiate it sufficiently from other trading to qualify it as a true institutional innovation. Irwin's interpretation of the evolution of futures trading is adopted by Hieronymus, who also appropriately extends the interpretation to the more recent evolution of the futures markets in the soybean complex. Transition to futures was essentially an industry response to problems attendant upon forward contracting in an expanding and intensely competitive market, as it had been in corn in the last century. Futures trading was re-invented in several trades, as it were, although the point might also be made that exchanges have more recently intensified their efforts to bring the discovery to other trades, including even such non-commodity trading as foreign exchange and residential mortgages.

Hieronymus next views futures markets against the requirements of pure competition, taking a statement by this reviewer as a point of departure and carrying the argument slightly out of bounds by stating (p. 105) that "futures trading is no more or less evil than pure competition." Successive chapters then enunciate the risk-shifting and equity-financing roles of futures trading; and the section on economics concludes with chapters on speculative pricing and hedging as arbitrage between cash and futures prices. The only italicized statement in the former chapter says that *"changes in price level, thus, are the result of speculative error"* (p. 142). This implies a view that speculators are mistaken if they do not foresee a drought, a blight, or a war. More generally, in Working's words, "It involves supposing that the market should act as a forecasting agency rather than as a medium for rational price formation when it cannot do both" [1]. The very theory of intertemporal price relationships which Hieronymus embraces in his next chapter rests squarely upon the premise that the futures market is a medium for rational price formation. Part III deals with the use of futures markets and reflects Hieronymus' considerable familiarity with a wide spectrum of commercial usage, including seven categories of warehousemen and merchants, five categories of processors, and primary producers. One consequence of treating so many categories of commercial users is that Hieronymus does not provide detailed or extended evidence for any particular category. It is worthwhile, however, to have brought out the differing considerations confronting various users, whereas an instructor employing this text could very well probe further into the hedging practices of particular users.

Part III also contains some new evidence on the financial results of speculation from which Hieronymus extracts some interesting conclusions, particularly as to the importance of commissions in the net results in his sample and the contrast between regular and occasional or one-time traders. We would like to know more about his samples—its ratio of long to short positions and its distribution of positions by commodities. Both of these (and other characteristics) could be compared with larger aggregates (e.g., the totals for the one commission firm or the patterns of non-reporting traders in the regulated markets, etc.) to help us assess the representativeness of the sample. Perhaps we shall have a more thorough analysis of these valuable data in a later publication.

The last part of the book deals with market performance and regulation. One performance test entails the costs of hedging, which Hieronymus places at zero in the well-developed markets. He refers to my conclusions on the risk premium question (p. 286n.) but neglects to adduce (at this point) Working's evidence regarding execution costs which he partially dismissed earlier (p. 249). He also rates market performance on price variability and on price forecasting.

Hieronymus contends that market regulation has displayed an antispeculation bias. Statutory regulation does aim to prevent "excessive" speculation, and this is, as Hieronymus points out, difficult to define and identify. Speculative position limits are in fact modified from time to time, and I suppose that it is not difficult to obtain a hearing in such matters. While questioning whether these limits are generally burdensome, I would place the onus on exchanges to demonstrate this where it is so. I suspect, with Hieronymus, that "orderly liquidations" tend to favor holders of short positions; but I am also inclined to think that his final prescription—"Let them trade out." (p. 312)—is a rather cavalier oversimplification. The statistics of a natural squeeze and a deliberate manipulation will look very similar—the difference for the courts to decide relates to intent. But the exchanges have an obligation to maintain contracts which

will not lead to repeated blurrings of the distinction. If a futures market has to draw stocks out of position to satisfy delivery requirements, natural squeezes will emerge. But when people begin trading in the expectation of these "natural" squeezes, the line between natural and planned is easy to cross. While agreeing with Hieronymus' basic interpretation of the May 1963 wheat episode at Chicago (p. 310), I also think that a market which regularly attracts fewer stocks than the delivery month open interest and occasionally attracts stocks lower than the speculative position limit for one trader will come to evoke so many natural squeezes that no trader can leave them out of his planning. To simply "let them trade out" will then be to let them trade out of business—which both the exchanges and the C.E.A. have an obligation to prevent.

My general feeling regarding the chapter on market regulation extends in lesser degree to other parts of the book. It is that the light touch of *obiter dicta*, the casual use of jargon, and the breezy (not to say flippant) style conspire to flaw the book. It is as though the author's very familiarity with the institution imbues him with a contempt for the rigor with which it must be explained to others. To illustrate the difficulty without belaboring: the reader finds hedgers colorfully characterized as "nulls" and "eunuchs" in price determination (p. 142), learns elsewhere that the perfect hedge is the one that makes all the money (p. 150), reads on the jacket that hedgers are more interested in the game than the money, and finds in the introduction that market dominance is more apt to be accomplished by hedgers than speculators (p. xiii). Yet, nowhere is it explicitly acknowledged that the hedger's concern with basis profits necessarily imparts a concern with futures prices (which are one side of the basis). Or similarly, a temporal price constellation which simply cannot be identified as such is referred to as "classic normal backwardation" (p. 81); another normal backwardation reference (p. 194) is clearly confused with inverse carrying charges (a confusion of which we had been warned on p. 163). When normal backwardation is finally defined (p. 246), it is done very carelessly and subsequently (pp. 285–286) confused with generalized market bias. A textbook should do better justice to the literature and to its author's own knowledge.

What the book lacks in rigor and internal consistency is partially offset by a good organization and selection of topics and by the inclusion of valuable materials, especially in Parts I and III. With adequate supplementation and clarification of theoretical issues and with reference to available evidence on these issues, this book can be a useful introductory textbook. Meanwhile, Hieronymus might meet instructors halfway by planning a revision taking account of these matters, including selected references, and a very careful editing to cull out undefined jargon, unsupported generalization, and loose characterization.

Roger W. Gray
Stanford University

Reference

[1] Working, Holbrook, "Theory of the Inverse Carrying Charge in Futures Markets," *J. Farm Econ.* 30:14, Feb. 1948.

Kilby, Peter, ed., *Entrepreneurship and Economic Development*, New York, The Free Press, 1971, viii + 384 pp. ($12.00)

Peter Kilby has collected several papers from debates over whether entrepreneurial talents made economies develop. The reader will find the classic theories of Schumpeter and Weber and the elaborations by Cochran, McClelland, and Hagen that present exogenous entrepreneurs as prime movers. A sociological interpretation by Frank W. Young and Kunkel's behavioral theory present entrepreneurial activities as somewhat more endogenous to the economic process. Besides the seven "theories of entrepreneurial supply," the book includes a selection of case studies of underdeveloped countries. Kilby's introductory article and two papers, Young's "Macrosociological Interpretation of Entrepreneurship" and E. Wayne Nafziger's "Indian Entrepreneurship: A Survey," are published here for the first time. Other papers are reprinted. Kilby has uncovered succinct statements of position from several authors, rather than reprinting longer selections from familiar books. Weber is presented in an interpretation by Ronan Macdonald; the other theorists speak for themselves.

This volume will be useful for development courses, but it is not only a teaching package. By juxtaposing the basic positions, Kilby raises questions about the entrepreneurship debate itself.

It becomes clear that entrepreneurship can mean all things to all men. To some, it is the ability of rare individuals or groups to make fundamental changes in an economy; to others, it is the more prosaic skill of adapting and managing. To some, the key question is whether a country's economy will grow; to others, it is a question of which individuals or groups will lead in and take advantage of the growth. To some, entrepreneurship is necessarily good; to others (underrepresented in this volume), it is dangerous, emerging from a community to destroy its *gemeinshaft* as it develops its economy.

Nor are "theories of entrepreneurial supply" free from an admixture of demand elements. Schumpeter himself said that leadership was a problem only when opportunities existed. The selection from his *Theory of Economic Development* shows he assumed the availability of credit in his treatment of entrepreneurship and the circular flow. Kunkel introduces the effect of demand, at least with a lag, by presenting entrepreneurship as a response to positive rein-

forcements to innovation. Some of the case studies also present an interpretation of entrepreneurship much more demand-oriented. The groups with opportunities become entrepreneurs in many cases in India, Pakistan, and Nigeria. Some case studies do concern only the supply side issue of the identity and motives of innovators. Kasdan debates Hagen over whether loss of status in Colombia or social structure in Basque Spain made the Antioquenos entrepreneurs; Hirschmier and Yamamura differ over whether Samurai patriotism or simple drives for wealth created the Japanese entrepreneur. But as Nafziger's review of the Indian example points out, even what may appear to be an anti-entrepreneurial culture may have adopted that form in response to lack of opportunity: colonial exclusion of the Bengalis from modern business activities competitive with the British. Unfortunately, a pure demand theory is not presented, although some have come close. (Marx's presentation of the need for businessmen to have landless labor before they can become industrial capitalists might have represented this position.)

Kilby presents a careful review of the theories in his introduction and incorporates a framework for sorting out elements of supply and opportunity. At one point he confuses definitions of the issue, arguing that productivity can be improved by better management in underdeveloped countries and then citing Israel as one of the countries in which ILO missions improved productivity. This speaks to a different point than the main theme of whether innovators are relatively scarcer in underdeveloped countries and whether innovation is the missing link for development. Still, most of the attention of the analysis is to this main point which Kilby introduces as "Hunting the Heffalump." This is a good guidebook for the hunt.

MATTHEW EDEL
Massachusetts Institute of Technology

Scherer, F. M., *Industrial Market Structure and Economic Performance*, Chicago, Rand McNally & Co., 1970, xi + 576 pp. ($13.00)*

Scherer tells us in the preface that he spent almost four years writing this book. It was worth it. Both substantively and stylistically, the book is excellent. It can well be used, as Scherer suggests, as a text in courses on industrial organization (and agricultural marketing) offered to graduate students or to strong undergraduates.

Scherer's approach is like Bain's. Neither covers all relevant government programs, like Wilcox, nor details the operation of a variety of industries, like Weiss. Both stress associations among market structure, conduct, and performance. Where Bain focuses on direct structure-performance associations, however, Scherer stresses the conduct that connects the two. Scherer has a chapter on welfare theory, two chapters on existing structures and their determinants, four on pricing by oligopolists, one on countervailing power, one on price discrimination, one on pricing by conglomerates, two on the implications of price rigidity, one on product differentiation, two on technological innovation and the patent system, one appraising performance throughout the American economy, four on antitrust policy, and one on public regulation. All of these topics are covered in an unusually edifying way, with extensive bibliography and many useful suggestions for further research.

For a book so big and ambitious, there are amazingly few slips. Let me, nevertheless, mention 8 points that I think a second edition could strengthen.

1. Scherer abuses some statutes. He states (pp. 424, 434) that section 7 of the Sherman Act authorizes treble-damage suits. Actually, this section was superseded by section 4 of the Clayton Act and repealed in 1955. It is also wrong to say (p. 426) that Congress has authorized price fixing by coops and that the subject is "relatively uncontroversial" because "cooperatives seldom possess much power." And it leaves gaps to ignore marketing orders, the Packers and Stockyards Act, and state antitrust and below-cost laws.

2. Scherer's discussion of market delineation is disturbing. He refers to high cross-elasticities of demand without pointing out that cross-elasticities are likely to vary with levels of prices (see cellophane) and that how soon customers would shift makes a difference. Also, he clouds the distinction between concentration and ease of entry by indicating (p. 53) that a market includes "groups of firms producing completely noncompeting products . . . if there are no barriers preventing each group from entering the other's product lines."

3. Scherer (like everyone else) treats concentration of sales as a determinant of, rather than a result of, market conduct. In fact, in markets with administered prices the size distribution of a period's sales is (like changes in shares between periods) a result of suppliers' decisions as to prices, promotion, etc., and of demanders' decisions as to purchases. Concentration of sales belongs to the set of predetermined variables that explain conduct or performance only in the sense that it can serve as a proxy for a variable that does belong, such as concentration of capacity.

4. Scherer is ambiguous concerning the relation of profitability or aggressiveness to concentration. Some economists think that, given high barriers to entry, etc., the conditional expectation of profitability is a constant below some level of concentration (Bain suggests 70 percent by eight) and a higher constant

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* This review is Giannini Foundation Research Paper No. 345.

above that level; others visualize or fit multi-level or continuous functions. There is also disagreement concerning the effect of changes in inequality among suppliers. Mergers among the smaller members of an industry raise both issues. Scherer does not contrast the alternatives and in fact writes (pp. 60, 183–186, 208) as if both views were correct.

5. Scherer's concept of performance is regrettably narrow. He applies norms for productive efficiency (covering not only the usual aspects of scale, utilization, and vertical integration, but also cross-hauling, mislocation, excessive inventories, organizational slack, and sales promotion), technological progress, distributive equity, and allocative efficiency. He does not, however, explore whether products are satisfactory with respect to durability, reliability, hazards, standardization, variety, etc.; nor whether exchange is efficient in terms of search, waiting, and transaction costs, interarea price differences, fraud, etc.; nor whether externalities are optimal in terms of avoiding some and providing others; nor whether conservation is adequate; nor whether consumers (and businessmen!) are making rational choices; etc. By these omissions, Scherer perpetuates the tradition of considering not all avoidable and objectionable consequences of market conduct but only those that have been associated with "excessive market power."

6. Scherer's norms for productive efficiency and technological progress are oversimplified. He presumes (pp. 33, 200, 347) that any expenditure which could be eliminated without "adverse effects on production" is undesirable and that any innovation which raises productivity is desirable. These norms give no weight to adverse effects on workers, owners, or other losers.

7. Scherer's defense of his distributive norm is inadequate. His norm is no "monopoly profits." But he never tells us how to separate monopoly profits from returns to innovation, cost reduction, shifting demand, and risk bearing. And his case rests (pp. 19, 409) on the "debatable premise" that reducing the incomes of people who bought stock at prices that capitalize monopoly profits will "add to total society-wide utility."

8. Scherer's defense of his allocative norm is inadequate. His norm is every product price equal to long-run marginal cost (the latter presumably being a weighted average if price is rigid and production and LRMC vary). After deriving (the short-run relative of) this norm from the Pareto criterion, Scherer himself presents most of the reasons (the major omission being externalities) why nothing follows (Chs. 2, 22). He even observes (p. 26), "[O]ne may decide that the whole question of allocative efficiency is so confused . . . that policy-makers should . . . base their choices on other criteria. . . ." But he rejects this conclusion because it is "unpalatable to most economists." Now, unpalatability, or rather ego damage, is no argument, and even it may change when economists recognize that $P = MC$ is not our only allocative norm. I should add that Scherer's revision of Harberger's and Schwartzman's estimates of the welfare loss from misallocation uses figures that Schwartzman later corrected, ignores a contribution by F. W. Bell, and is 1.05 percent of GNP on p. 404 and 1.5 percent on p. 408.

Such slips, however, are minor. Overall, the book is, I repeat, excellent.

Stephen H. Sosnick
University of California, Davis

Solow, Barbara Lewis, *The Land Question and the Irish Economy, 1870–1903*, Cambridge, Harvard University Press, 1971, ix + 247 pp. ($8.50)

Basic problems of most underdeveloped countries are their landlord-tenant systems and their large number of inefficient farms. These problems were severe in Ireland. In 1871, 50 percent of the farms were under 15 acres and 85 percent under 50 acres. Many of these small farms became intolerable after 1876 when cheap grains mostly from the midwestern United States flooded European markets and caused a 50 percent drop in grain prices.

Why were these small farms not consolidated and improved to meet this competition? Solow points out that even today the "best historians specializing in the Victorian period" believe the main cause was an unsatisfactory landlord-tenant system. But she challenges this view as a myth in a provocative, highly discussible book that should be of much interest to students of the role of land tenure and government programs in economic development.

In what way was the Irish tenure system deemed to be defective? Before 1870 the basic Irish tenure laws were much the same as they then were in England and are today in much of Canada, Australia, and the United States. In Ireland the rule was oral year-to-year leases which could be terminated by the landlord for any reason or no reason on six months' notice except where Ulster custom prevailed. Under this custom, the landlords undertook never to evict a rent-paying tenant, to allow tenants to make their own improvements and sell them to the oncoming tenant when they leave, and to increase rents only as justified by increased land values.

Irish tenants admired Ulster custom of the "three F's": fixity (security) of tenure, free sale of improvements, and fair rent. Hence, they demanded it be made universal by law, and it was so done by the Landlord-Tenant Act of 1870 and the Land Act of 1881.

Was this legislation necessary or desirable? Solow examined the evidence from 1850–1880 and found that tenants already enjoyed a high degree of the three F's. Less than 3 percent were being evicted by landlords. Rent increases were modest and in line with increased productivity and rents in Scotland and England. Improvements, however, were another matter. Landlords often shared the cost of improve-

ments on the larger farms but on the smaller farms "anything that was done frequently tended to *decrease* the value of the land." On these small inefficient holdings "every fence or cottage represented a negative return; they would have to be torn down and leveled in order to raise the productivity of the land" (p. 79), much as is now done in slum clearance projects. Hence, the landlord simply could not make improvements because the tenants could not pay additional rent for them. Solow found "ample evidence that the flow of capital into Irish agriculture was impeded by the inability of landlords to establish farms of optimal size and to introduce improved farming techniques. It was the prevailing tenure customs—of not evicting and not charging market prices for rent—that blocked the way" (p. 84). Hence, she concluded that the Land Acts of 1870 and 1881 which granted the three F's plus rent reductions and rent controls were steps in the wrong direction—steps that inhibited economic development by landlords. What is somewhat missing here is recognition that with the three F's tenants could now make profitable improvements but, like their landlords, they could not make investments for which there was no hope of return, as was the case on most small holdings. Solow does not mention the possibility that tenants with zero opportunity cost for their labor might be able to make more improvements than landlords who would have to hire workmen and raise rents to cover his increased investment. She also neglects the possibility that tenants could consolidate holdings more effectively than landlords by buying the leases of their neighbors just as they have bought nearby farms after 1903 when they became full owners.

In the 1850's there were about 600,000 farmers in Ireland; by the 1960's there were only about 300,000 in all Ireland. Could Irish landlords have done better than this? Solow presents no evidence that they could. Indeed, her evidence makes clear that landlords dared not consolidate for fear for their lives. Because "fair rents" were less than competitive rents, Ireland was under a voluntary rent control system wherever Ulster custom existed and after 1881, when the rent control system became law. This experience is relevant today wherever rents are not competitive as is the case for 1.3 million apartments in New York City, for federal public lands in the West, and for the Scully Estates lands in Illinois, Nebraska, and Kansas.

RUSSELL L. BERRY
South Dakota State University, Brookings

Books for listing in this section should be sent to the Book Review Editor (see inside front cover for address).

Books Received

Arrow, Kenneth J., and F. H. Hahn, *General Competitive Analysis*, San Francisco, Holden-Day, Inc., 1971, xii + 452 pp. $15.95.

Ashton, J., and W. Harwood Long, eds., *The Remoter Rural Areas of Britain*, Edinburgh, Oliver & Boyd, 1972, x + 246 pp. £2·50.

Balassa, Bela, and Associates, *The Structure of Protection in Developing Countries*, Baltimore, The Johns Hopkins Press, 1971, xviii + 375 pp. $12.00.

Ball, A. Gordon, and Earl O. Heady, eds., *Size, Structure, and Future of Farms*, Ames, The Iowa State University Press, 1972, viii + 404 pp. $9.95.

Brubaker, Sterling, *To Live on Earth: Man and His Environment in Perspective*, Baltimore, The Johns Hopkins Press for Resources for the Future, Inc., 1972, xiv + 202 pp. $6.95.

Bucklin, Louis P., *Competition and Evolution in the Distributive Trades*, Englewood Cliffs, Prentice-Hall, Inc., 1972, xiv + 369 pp. $10.95.

Carnoy, Martin, *Industrialization in a Latin American Common Market*, Washington, D.C., The Brookings Institution, 1972, xxv + 267 pp. $8.95.

Castle, Emery N., Manning H. Becker, and Frederick J. Smith, *Farm Business Management: The Decision-Making Process*, 2nd ed., New York, The Macmillan Company, 1972, xxi + 340 pp. $9.50.

Clawson, Marion, *America's Land and Its Uses*, Baltimore, The Johns Hopkins Press for Resources for the Future, Inc., 1972, x + 166 pp. $8.50.

Dalton, George, ed., *Studies in Economic Anthropology*, Washington, D.C., American Anthropological Association, 1971, iii + 242 pp. Price unknown.

Day, Ralph L., and Leonard J. Parsons, eds., *Marketing Models: Quantitative Applications*, Scranton, Intext Educational Publishers, 1971, ix + 693 pp. $5.95.

de Neufville, Richard, and Joseph H. Stafford, *Systems Analysis for Engineers and Managers*, New York, McGraw-Hill Book Company, 1971, xiii + 353 pp. $14.95.

Dhrymes, Phoebus J., *Distributed Lags: Problems of Estimation and Formulation*, San Francisco, Holden-Day, Inc., 1971, ix + 414 pp. $14.95.

Dorner, Peter, ed., *Land Reform in Latin America: Issues and Cases*, Madison, Land Economics for the Land Tenure Center, 1971, xx + 276 pp. $3.95. Paper.

Dovring, Folke, and Karin Dovring, *The Optional Society: An Essay on Economic Choice and Bargains of Communication in an Affluent World*, The Hague, Martinus Nijhoff, 1971, x + 107 pp. Price unknown. Paper.

Evans, John W., *The Kennedy Round in American Trade Policy: The Twilight of the GATT?*, Cambridge, Harvard University Press, 1971, xiii + 383 pp. $13.95.

Frankel, Francine R., *India's Green Revolution: Economic Gains and Political Costs*, Princeton, Princeton University Press, 1971, x + 232 pp. $7.50.

Gandolfo, Giancarlo, *Mathematical Methods and Models in Economic Dynamics*, New York, American Elsevier Publishing Company, Inc., 1971, x + 511 pp. $14.50. Paper.

Grogan, F. O., ed., *International Trade in Temperate Zone Products*, Edinburgh, Oliver & Boyd, 1972, xiv + 313 pp. £2·50.

Grubel, Herbert G., and Harry G. Johnson, eds., *Effective Tariff Protection*, New York, Unipub, Inc., 1971, vii + 305 pp. $7.50.

Heady, Earl O., Leo V. Mayer, and Howard C. Madsen, *Future Farm Programs: Comparative Costs and Consequences*, Ames, The Iowa State University Press, 1972, viii + 411 pp. $11.95.

Hughes, Harold D., and Darrel S. Metcalfe, *Crop Production*, 3rd ed., New York, The Macmillan Company, 1972, xi + 627 pp. $13.75.

Kneese, Allen V., and Blair T. Bower, eds., *Environmental Quality Analysis: Theory and Method in the Social Sciences*, Baltimore, The Johns Hopkins Press for Resources for the Future, Inc., 1972, ix + 408 pp. $12.00.

Kneese, Allen V., Sidney E. Rolfe, and Joseph W. Harned, eds., *Managing the Environment:*

International Economic Cooperation for Pollution Control, New York, Praeger Publishers, Inc., 1971, xxxvii + 356 pp. $15.00

Kohls, Richard L., and W. David Downey, *Marketing of Agricultural Products,* 4th ed., New York, The Macmillan Company, 1972, xii + 432 pp. $10.75.

Lipset, S. M., *Agrarian Socialism: The Cooperative Commonwealth Federation in Saskatchewan,* rev. ed., Berkeley, University of California Press, 1971, xxiv + 487 pp. $3.85. Paper.

Mah, Feng-hwa, *The Foreign Trade of Mainland China,* Chicago, Aldine-Atherton, Inc., 1971, xvii + 270 pp. $9.75.

Maktari, A. M. A., *Water Rights and Irrigation Practices in Lahj,* London, Cambridge University Press, 1971, x + 202 pp. $16.00.

Meadows, Dennis L., *Dynamics of Commodity Production Cycles,* Cambridge, Wright-Allen Press, Inc., 1970, xi + 104 pp. $14.75.

Mosher, A. T., *To Create a Modern Agriculture: Organization and Planning,* New York, The Agricultural Development Council, Inc., 1971, xiv + 162 pp. Price unknown. Paper.

Myint, H., *Economic Theory and the Underdeveloped Countries,* New York, Oxford University Press, 1971, xii + 353 pp. $3.95. Paper.

O'Neill, Helen B., *Spatial Planning in the Small Economy: A Case Study of Ireland,* New York, Praeger Publishers, 1971, xv + 221 pp. $15.00.

Pazer, Harold L., and Lloyd A. Swanson, *Modern Methods for Statistical Analysis,* Scranton, Intext Educational Publishers, 1972, ix + 483 pp. $12.00.

Prothero, R. Mansell, ed., *People and Land in Africa South of the Sahara: Readings in Social Geography,* New York, Oxford University Press, 1972, viii + 344 pp. $4.95. Paper.

Rasmussen, Wayne D., and Gladys L. Baker, *The Department of Agriculture,* New York, Praeger Publishers, 1972, xii + 257 pp. $9.00.

Reichard, Robert S., *The Numbers Game: Uses and Abuses of Managerial Statistics,* New York, McGraw-Hill Book Company, 1972, xiv + 366 pp. $11.50.

Rosenbaum, H. Jon, and William G. Tyler, eds., *Contemporary Brazil: Issues in Economic and Political Development,* New York, Praeger Publishers, 1972, xviii + 438 pp. $20.00.

Runner, Tim, *Cattle Investments,* Redlands, Cattle Investments, 1971, ii + 70 pp. $6.00. Paper.

Singh, Tarlok, *Poverty and Social Change with A Reappraisal,* 2nd ed., Bombay, Orient Longmans Ltd., 1969, xiv + 352 pp. Rs. 25.

Sturrock, Ford, *Farm Accounting and Management,* 6th ed., Bath, Great Britain, Pitman Publishing Company, 1971, ix + 262 pp. £2·20. net.

Teskey, Benjamin J. E., and James S. Shoemaker, *Tree Fruit Production,* 2nd ed., Westport, The AVI Publishing Company, Inc., 1972, viii + 336 pp. $15.00.

Whitcombe, Elizabeth, *Agrarian Conditions in Northern India, Vol. I: The United Provinces under British Rule 1860–1900,* Berkeley, University of California Press, 1972, xviii + 330 pp. $12.00.

Wills, Walter J., *An Introduction to Grain Marketing,* Danville, The Interstate Printers and Publishers, Inc., ii + 155 pp. $9.25.

Yudelman, Montague, and Frederic Howard, *Agricultural Development and Economic Integration in Latin America,* London, George Allen and Unwin Ltd., 1970, 336 pp. Price unknown.

Zarnowitz, Victor, ed., *The Business Cycle Today,* New York, National Bureau of Economic Research, Inc., 1972, xiii + 338 pp. Price unknown. Paper.

Zellner, Arnold, *An Introduction to Bayesian Inferences in Econometrics,* New York, John Wiley & Sons, Inc., 1971, xv + 431 pp. $19.95.

Announcements

AAEA-ASSA
1972 Winter Meeting

The American Agricultural Economics Association will meet jointly with the Allied Social Sciences Association in Toronto, Canada, in December. A complete program will be published in the November AJAE.

Sessions are scheduled in the following areas:

Agricultural Credit and Rural America (joint session with the American Finance Association)

Validity and Verification in the Modeling of Complex Systems (joint session with the Econometric Society)

The Relation of Canadian and U.S. Agriculture in International Trade.

New Journal

The editors and publishers are pleased to announce the *Public Finance Quarterly,* a new scholarly journal for the study of theory, policy, and institutions related to the allocation, distribution, and stabilization functions of the public sector.

PFQ will begin publication in January 1973. Original contributions in all areas of public finance are invited, and articles will be reviewed promptly by distinguished referees. Books will also be reviewed.

Inquiries should be directed to the editors:

Irving J. Goffman, Editor
J. Ronnie Davis, Assistant Editor
Public Finance Quarterly
Department of Economics
University of Florida
Gainesville, Florida 32601.

Subscriptions to the *Public Finance Quarterly* may be placed with the publishers, Sage Publications, Inc., 275 South Beverly Drive, Beverly Hills, California 90212. Yearly subscription rate (U.S. and Canada), $18 ($12 to individual professionals; $9 to students). Overseas orders, $19 (no discounts to professionals and students).

International Association of Agricultural Economists
Competition for Contributed Papers

A competition for contributed papers is being arranged in connection with the 1973 IAAE Conference. Entries are invited from members and nonmembers on topics in any field of agricultural economics. (If papers from nonmembers are selected for reading, the nonmembers will be expected to join the Association.) Further particulars are available from either IAAE country correspondents or Dr. Kenneth R. Farrell, Deputy Administrator, Economic Research Service, USDA, Washington, D.C. 20250.

News Notes

UNIVERSITY OF ARIZONA

LEAVE: **John L. Fischer,** as an advisor to Turkey's Ministry of Agriculture on agricultural policy, for two years, underwritten by the University of Arizona/AID contract.

CORNELL UNIVERSITY

APPOINTMENT: **David Penny,** of the Australian National University, as visiting research fellow for 1972–73.

LEAVES: **Robert J. Kalter,** one-year sabbatical to the Secretary's Program Evaluation Staff, Department of Interior; **Daniel I. Padberg,** one-year sabbatical to the University of Manchester, England.

ECONOMIC RESEARCH SERVICE, USDA

(EDD, Economic Development Division; ESAD, Economic and Statistical Analysis Division; FDCD, Foreign Demand and Competition Division; FDD, Foreign Development Division; FPED, Farm Production and Economics Division; MED, Marketing Economics Division; NRED, Natural Resource Development Division.)

APPOINTMENTS: **Peter Emerson,** MED; **Richard Haynes,** ESAD; **Howard Hogg,** NRED; **Phillip T. Allen,** FPED, from Agricultural Finance Branch to assistant field research coordinator, Office of the Director; **John H. Berry,** FPED, appointed chief of Production Resources Branch; **George Irwin,** FPED-Indiana, appointed acting Southern Field Group head; **Rudie W. Slaughter,** FPED, appointed chief of the Production Adjustments Branch; **John Stovall,** FPED, from head of the Southern Field Group to acting Field Research coordinator in the Office of the Director.

REASSIGNMENTS: **Larry M. Boone,** FDCD to NRED-Lincoln, Nebraska; **G. Stanley Brown,** FDCD to Foreign Agricultural Service as assistant attache in Moscow; **Richard N. Brown,** NRED to EDD; **Alan B. Carr,** from FPED to Office of the Secretary; **J. C. Chai,** from ESAD to Food and Nutrition Service; **O. A. Cleveland, Jr.,** MED-Washington, D. C., to Stillwater, Oklahoma; **Velmar W. Davis,** FPED to acting assistant to the administrator, ERS; **Ronald L. Drake,** NRED-Berkeley to Washington, D.C.; **Lawrence Duewer,** MED-Lafayette, Indiana, to Washington, D.C.; **Burton L. French,** FPED-Washington, D.C., to the Price Commission; **Herbert Hoover,** from EDD to NRED-Columbia, Mo.; **Edgar Lewis,** from EDD to ESAD; **Harold Linstrom,** USAID-Brazil to MED-Washington, D.C.; **Malek M. Mohtadi,** FDCD to the Price Commission; **Carmen Sandretto,** NRED-East Lansing, Mich., to Washington, D.C.; **Lyle P. Schertz,** deputy administrator, Foreign Economic Development Service, to deputy administrator, ERS; **Harold M. Stults,** NRED-Davis, Cal., to Denver, Colorado; **John E. Subat,** FPED to the Office of the Secretary; **Larry Summers,** MED to ESAD; **H. Charles Treakle,** FDCD, to Food and Agricultural Organization, Rome.

RESIGNATIONS: **J. Dawson Ahalt,** ESAD, to a permanent appointment with the Price Commission; **James A. Burns,** NRED; **William A. Elder,** FPED-Minn.; **Milton Holloway,** NRED; **James A. Munger,** from NRED to the Department of Interior; **M. Glade Pincock,** NRED; **Harold Yee,** MED; **Peter B. Ziesmer,** MED.

RETIREMENTS: **Roy Ballinger,** MED; **Edwin T. Bardwell,** MED; **Victor Edman,** MED; **William F. Hughes,** FPED-Texas; **Clive Johnson,** MED; **Elfriede A. Krause,** FDCD; **Mary E. Long,** FDCD; **Ronald L. Mighell,** FPED; **Clarence E. Pike,** FDCD; **Thomas B. Smith,** MED; **Robert M. Walsh,** ESAD.

UNIVERSITY OF FLORIDA

APPOINTMENT: **Peter E. Hildebrand,** formerly with the University of Nebraska mission in Colombia, has accepted a two-year assignment as project leader with the El Salvador/UF contract in San Salvador.

UNIVERSITY OF GEORGIA

APPOINTMENTS: **M. Dean Ethridge,** Ph.D. University of California at Berkeley; **George K. Flaskerud** and **Fred C. White,** Ph.D.'s Oklahoma State

University, assistant professors of agricultural economics; **Mac Reese Holmes**, Ph.D. Mississippi State University, assistant professor, Georgia Experiment Station.

UNIVERSITY OF GUELPH

Return: **J. H. Clark**, associate professor, has returned from a two-year assignment as agricultural advisor to the Foundation of Canadian Engineering Corporation's masterplan study in Malaysia.

UNIVERSITY OF IDAHO

Retirement: **William E. Folz**, professor, after 37 years of service to the university and 21 years as head of the Department of Agricultural Economics.

IOWA STATE UNIVERSITY

Appointments: **Raymond R. Beneke**, professor, as acting head of the Department of Economics, replacing **Karl A. Fox**, who will be doing research at the University of California at Santa Barbara and Berkeley; **Thomas P. Drinka**, research associate.

KANSAS STATE UNIVERSITY

Appointment: **Richard Fenwick, Jr.**, Ph.D. Missouri, extension economist in marketing information and agricultural firm management.

Awards: **Emery N. Castle**, former head of the Department of Agricultural Economics, Oregon State University, received the Gamma Sigma Delta Distinguished Alumnus Award; **John B. Sjo** was awarded an Outstanding Teacher Award by KSU's Gamma Sigma Delta chapter.

Retirement: **George Montgomery**, after 47 years of service.

Return: **John H. McCoy** has returned from a one-year sabbatical at the University of Arizona.

UNIVERSITY OF MAINE AT ORONO

Appointment: **Kenneth E. Wing**, associate professor, as chairman of the department, effective July 1, 1972.

Leave: **Reginald K. Harlan**, associate professor, to Central Luzon State University, Philippines (UNESCO contract), one year.

UNIVERSITY OF MARYLAND

Leave: **Dean F. Tuthill** is on a one-year sabbatical (to August 1, 1973) on a Senior Fulbright-Hays Scholarship to the University of Zambia, Zambia, Africa.

UNIVERSITY OF MASSACHUSETTS

Leave: **Elmar Jarvesoo**, to the University of Freiberg, Germany, for the fall semester, as a visiting professor in the Department of Economics and as a resident faculty member of the University of Massachusetts Freiberg Cooperative Program.

MICHIGAN STATE UNIVERSITY

Appointments: **Thomas Pierson**, Ph.D. Cornell, assistant professor, with research and extension responsibilities in the marketing area; **Leanna Stiefel**, Ph.D. Wisconsin, assistant professor, with teaching and research responsibilities in public finance.

Leave: **John Allen**, to the University of Sweden, August-December.

UNIVERSITY OF MINNESOTA

Leave: **James P. Houck**, professor, who spent 1971–72 in Thailand, will be on sabbatical furlough in 1972–73, as a visiting professor in the agricultural economics department at the University of Sydney, Australia, July-December 1972.

UNIVERSITY OF MISSOURI

Appointment: **J. Wendell McKinsey**, professor, appointed assistant dean of the Missouri College of Agriculture and director of the College International Programs in Agriculture.

Awards: **Kenneth B. Boggs**, Gamma Sigma Delta Outstanding Teacher Award; **Harold F. Breimyer**, Gamma Sigma Delta Senior Faculty Award of Merit.

OKLAHOMA STATE UNIVERSITY

Resignation: **Ivan Hanson**, associate professor, to the Department of Health Administration, College of Health, University of Oklahoma Health Science Center.

OREGON STATE UNIVERSITY

Appointment: **Emery N. Castle**, formerly head of the department, dean of the Graduate School.

PURDUE UNIVERSITY

Appointment: **Monte E. Juillerat**, professor, appointed assistant dean of faculty at Indiana University-Purdue University Campus, Indianapolis, effective July 1.

SOUTH DAKOTA STATE UNIVERSITY

Appointment: **Robert E. Olson**, formerly of the Stanford Research Institute, with responsibilities in livestock marketing, teaching, and research.

Resignation: **Raymond O. Gaardner**, to accept a position with the Near East Foundation, USAID, in Dar es Salaam, Tanzania, East Africa.

STANFORD UNIVERSITY, FOOD RESEARCH INSTITUTE

Appointments: **Walter P. Falcon**, former deputy director of the Harvard Development Advisory Service, as director and professor, effective Sept. 1, 1972; **Frank W. Oechsli**, Ph.D. candidate University of California, as research demographer and acting assistant professor.

Leave: **Benton F. Massell**, professor, program

manager, Division of Social Systems and Human Resources, National Science Foundation, for 15 months, beginning June 15.

VANDERBILT UNIVERSITY

LEAVE: **William H. Nicholls,** professor, will spend the 1972–73 academic year in Brazil completing a research project.

UTAH STATE UNIVERSITY

APPOINTMENT: **B. Delworth Gardner,** head of the combined Departments of Economics and Agricultural Economics.

WASHINGTON STATE UNIVERSITY

APPOINTMENT: **J. Edwin Faris,** former head of the department at Virginia Polytechnic Institute, chairman of the Department of Agricultural Economics, effective July 1.

OTHER APPOINTMENTS

Marvin S. Anderson, Ph.D. Cornell, assistant professor, University of Alberta, Canada.

Fred Benson, Ph.D. Missouri, assistant professor of agricultural economics, University of Maine.

Johannes de Graaf, Ph.D. Missouri, OECD, Dairy Production Marketing, Paris, France.

Otto C. Doering, Ph.D. Cornell, assistant professor, Purdue University.

Sadok Driss, M.S. Missouri, assistant professor, University of Tunis, Tunisia.

Richard Eggers, M.S. Missouri, economist, Milk Market Administrator's Office, St. Louis.

Marvin Fausett, Ph.D. Missouri, area farm management specialist, University of Missouri Extension Division.

Donald F. Ferguson, Ph.D. Cornell, associate professor, Southern University Project, Cameroons, Africa.

José A. B. S. Girão, Ph.D. Cornell, Agricultural Economics Research Center, Gulbenkian Foundation, and assistant professor at the University of Lisbon.

Richard Green, Ph.D. Missouri, assistant professor of agricultural economics, Montana State University.

Estel Hudson, Ph.D. Missouri, from farm management advisor under the University of Tennessee contract in Bangalore, India, to professor of agricultural extension, University of Ghana, Legon, Ghana, Africa.

Harlan Hughes, Ph.D. Missouri, assistant professor of agricultural economics, University of Wisconsin.

Robert D. Hunt, Ph.D. Minnesota, International Bank for Reconstruction and Development, Washington, D.C.

Michael I. Kolawole, Ph.D. Cornell, lecturer, University of Ife, Nigeria.

Thomas V. Koszarek, Ph.D. Minnesota, Agricultural Extension Service, Medford, Wisconsin.

Cevdet Ogut, Ph.D. Missouri, teacher, University of Ataturk, Erzurum, Turkey.

James R. Owen, M.S. Wyoming, Farm Credit Banks, Omaha, Nebraska.

Gary Peabody, M.S. Missouri, USDA Dairy and Poultry Marketing News Service, Chicago.

Stephen Plank, M.S. Missouri, management trainee, Federal Land Bank, St. Louis.

Don D. Pretzer, Ph.D. Missouri, extension economist, Kansas State University.

Robert Retzlaff, Ph.D. Missouri, assistant professor, Central Missouri State College, Warrensburg.

Leonard A. Shabman, Ph.D. Cornell, assistant professor, Virginia Polytechnic Institute.

James W. Shatava, Ph.D. Minnesota, to Wisconsin State University, River Falls, Wisconsin.

Leslie E. Small, Ph.D. Cornell, assistant professor, University of Southern Illinois.

Thomas H. Stevens, Ph.D. Cornell, economist, Water Resources, State of Washington, Olympia.

J. L. Clovis Vellin, Ph.D. Cornell, general manager, Development Works Corp., Beau Bassin, Mauritius.

Bernard Yon, Ph.D. Cornell, assistant professor, Ecole Superieure des Sciences Economiques et Commercials, Paris, France.

OBITUARY

Dr. Norris T. Pritchard, 53, U.S. Department of Agriculture economist, died suddenly in his Washington, D.C. office April 18, 1972.

An international authority on food marketing, he had been with USDA's Economic Research Service for nearly 20 years. Dr. Pritchard had been a supervisory agricultural economist for International Development and Marketing with ERS's Foreign Demand and Competition Division since 1968.

Dr. Pritchard also served as agricultural advisor to the U.S. Delegation to the Sixth General Conference on Tariffs and Trade (Kennedy Round), 1964–66, and as an economic officer assigned to the Organization for Economic Cooperation and Development, 1966–68.

He authored many reports on foreign food marketing including *Food Marketing in West Germany: Developments, Prospects for 1980* and *The Swedish Market for Private Brand Foods* published this year. He wrote a special USAID report in 1970 on West African grain production and marketing.

Dr. Pritchard was born and received his early education in Milford, Iowa, receiving his B.A. from Northern Iowa University, his M.A. from the State University of Iowa, and his Ph.D. from Iowa State University. He taught economics at several universities and served as an officer in World War II. He was a member of the American

Agricultural Economics Association and the Canadian Agricultural Economics Society. Dr. Pritchard lived in Silver Spring, Md., with his wife Elfrieda and their children, Eric, Judith, and Brian.

ADDENDUM

Doctoral Degrees Awarded in Agricultural Economics In 1971, by Subject Area

V. AGRICULTURAL PRODUCTS: DEMAND, SUPPLY, PRICES

Zeng Rung Lui, B.A. Soochow University, Taipei, Taiwan, Republic of China; M.A. Vanderbilt University; Ph.D. Colorado State University, *Econometric Analysis of Colorado's Beef Industry.*

VII. ECONOMIC DEVELOPMENT, GROWTH, AND PLANNING

Debebe Worku, B.A. Haile Selassie University, Addis Ababa, Ethiopia; Ph.D. Colorado State University, *Economic Analysis of Water Use in Pakistan.*

XII. INDUSTRIAL ORGANIZATION

Clifford Peter Dobitz, B.A. Dickinson State College; M.A. North Dakota State University; Ph.D. Colorado State University, *Industrial Negative Externalities.*

Raymond Leonard Raab, A.B. Oakland University; M.A. University of Denver; Ph.D. Colorado State University, *Improving Census Industry Classifications.*

XIV. NATURAL RESOURCE ECONOMICS

Alphonse Henry Gilbert, B.S., M.S. Michigan State University; Ph.D. Colorado State University, *Determination of the Economic Demand and Value of Hunting and Fishing in Colorado.*

Robert Emerson Lovegrove, B.S.F. University of New Mexico; M.S.F. University of Montana; Ph.D. Colorado State University, *The Economic Impact of Fishing and Hunting on a Local Colorado Economy.*

XV. PRODUCTION ECONOMICS AND MANAGEMENT

Mansoor I. Alturki, B.S. Riyadh University, Saudi Arabia; Ph.D. Colorado State University, *Accelerating Agricultural Production.*

XVII. REGIONAL ECONOMICS

Adnan Abdulhadi Zindaki Daghestani, M.S. (Law) Damascus University, Syria; Ph.D. Colorado State University, *Analysis of Regional Multipliers.*

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